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H. FOSTER BAIN, DIRECTOR

SMOKE-ABATEMENT INVESTIGATION AT GRAFTON, W. VA.

BY

OSBORN MONNETT

AND

L. RUSSELL HUGHES

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SMOKE ABATEMENT INVESTIGATION AT GRAFTON, W. VA.

By Osborn Monnett and L. Russell Hughes

INTRODUCTION

This paper is published by the Bureau of Mines as a contribution to the literature on the abatement of smoke in cities. It shows how an exceptionally bad smoke situation was remedied by methods that are widely applicable, and hence it should be of value as a guide in a campaign to free any community suffering from a smoke-laden atmosphere due to the inefficient use of high-volatile coal in houses, industrial plants, and locomotives.

ACKNOWLEDGMENTS

Investigation of the conditions at Grafton was made possible through a cooperative arrangement with the Grafton Chamber of Commerce. Grateful acknowledgment is made of the active assistance rendered by members of that body during the preliminary investigation of conditions and by the Baltimore & Ohio R. R. officials in the campaign for abatement of smoke.

PURPOSES OF THE INVESTIGATION

The purposes of the investigation were to make a study of the atmospheric conditions of the city with special reference to smoke; to place the information gathered in such form as to be available for future reference; to determine the feasibility of reducing smoke to the minimum; and to make recommendations on the methods to be employed in bringing about this result.

CONDITIONS AT GRAFTON

Grafton, the county seat of Taylor County, W. Va., is situated in the north part of the State, midway between Cumberland, Md., and Parkersburg, W. Va., and about 75 miles due south of Pittsburgh. There is little level land in the vicinity and the city is built mainly on the steep slopes of the hills surrounding the junction of Three Fork Creek and Tygarts Valley River. Grafton is an important junction point on the Baltimore & Ohio R. R., lines branching from it in four directions.

TOPOGRAPHY

The peculiarly sheltered position of the city has a marked effect on the smoke conditions. To the north Grafton is bounded by hills on whose steep slopes is built the greater part of the residence district. To the south and west the winding valley of Tygarts Valley River makes a break in the hills. Three Fork Creek winds around the base of the hills to the east. Except for these outlets the city is completely encircled by high rolling hills.

CLIMATE

The prevailing direction of the wind is from the southwest; the average velocity is between 3 and 4 miles an hour. This velocity is not high enough to clear the valley of smoke.

The altitude of Grafton is 985 feet at the Weather Bureau station. The town enjoys an invigorating climate with moderately heavy rainfall and snowfall. Moderate variations of temperature from season to season and day to day are characteristic; the mean seasonal range is about 33° F. Extremes either of heat or cold are rare. Some meteorological data are given below.

Average temperature, rainfall, and snowfall by months

Month	Mean temperature ° F.	Mean rainfall	Mean snowfall
January	31.6	3.45	11.1
February	29.6	3.02	9.0
March	42.8	4.54	8.5
April	50.9	3.83	3.3
May	61.9	4.43	0.2
June	68.7	4.80	None.
July	72.6	4.91	None.
August	71.3	3.64	None.
September	66.6	2.61	None.
October	54.8	2.46	.4
November	43	3.08	2.8
December	31.4	3.44	7.0
Average annual	52.1	44.21	42.3

The average number of days a year without rain is 212.

AIR CURRENTS AND SMOKE MOVEMENT

In the morning the sun's rays fall first on the hills to the north and northwest. In consequence the air on the hillsides becomes warmer than that in the lower parts of the city. This warm air rises, creating an upward movement of the atmosphere that gradually draws the smoke up on the benches until the entire area is enveloped.

Later in the day, owing to the prevailing southwest wind, the smoke cloud is driven up over the hills to the north and northeast. In the late afternoon the wind usually sets in from the east and northeast, tending to disseminate the smoke over practically the entire city. Thus the local atmospheric situation is especially unfavorable as to smoke. Plate I, *A* and *B* (p. 6), show typical local conditions.

The Baltimore & Ohio R. R. taken as a unit, including shops and roundhouse, has been the main source of all the smoke made in Grafton. The smoke from four industrial plants constitutes a minor phase of the problem.

The main Southwest lines of the Baltimore & Ohio R. R. enter Grafton from the east and west. The tracks parallel Main Street and are within a few hundred feet of it. Thus the smoke from railroad operation dominates the business section. The shops, roundhouse, coal dock, and yards are a few hundred feet south of Main Street and largely affect the situation.

The Baltimore & Ohio east and west bound yards are in East Grafton and the main line east runs through these yards. North and south of the city the hills rise abruptly. On the hillsides to the north is the residence district of the east end of the city. A little farther east is Blueville, a surburb in which new homes are being erected. The prevailing southwest wind forces the smoky atmosphere into this residence district.

FOGS

During the winter months and in the rainy season, especially during April, fogs are frequent in Grafton. Fog usually begins to gather in the late afternoon, gradually becoming denser as the sun sets behind the hills, lasting through the night, and clearing up about 9 o'clock in the morning, except on cloudy days. This prevalence of fog greatly increases the smokiness of the air as it holds the smoke clouds down over the city.

Fogs are formed by moisture condensing on dust or smoke particles in the atmosphere; the more dust or smoke present the greater is the liability to the formation of fog when other conditions are favorable. Although smoke in the atmosphere is always conducive to the formation of fog, yet fogs such as those prevailing at Grafton are peculiar to mountainous regions and are especially frequent in valleys surrounded by high hills that are in winter covered continuously or intermittently with snow.

Thus the atmosphere of Grafton will always be liable to be foggy at certain periods of the year. This condition is peculiar to the locality and would prevail even if there were no smoke in the atmosphere.

PLAN OF CAMPAIGN

1. To investigate the atmospheric conditions of the city, placing on record the normal conditions in regard to smoke. This part of the work was to include three investigations. One was a Ringelmann chart survey from certain definite locations, covering the territory and including all classes of smokers. The latter were to be divided into roundhouse, yard engines, shop power house, road engines, and stationary power plants. The second investigation was to be a soot-

fall study covering the amount of solid matter precipitated at various locations throughout the city with results to be calculated in tons per annum per square mile. The third was a fuel survey to determine the amount and character, chemical composition, etc., of the coal used in the Grafton territory and the percentage of smoke made by each class of smoker based upon the above figures. Figure 1 gives a map of Grafton, showing the points where Ringelman readings, atmospheric filtrations, and soot-fall readings were made.

2. To accomplish such actual smoke abatement as was possible and to draft a program for continuing the work with the idea of reducing smoke to a commercial minimum in the district.

3. To make recommendations for permanent smoke-abatement measures.

INVESTIGATION OF SMOKE IN GRAFTON

RINGELMANN READINGS

When the campaign at Grafton was planned it was decided that observations and smoke-density determinations would be made for the first three months to get on record the conditions that existed before any smoke-abatement work was undertaken. The figures obtained during this time would then be available for comparison with similar figures taken later on which would show the degree of success attained in the work. In accordance with this plan a systematic series of Ringelmann charts were made for all hours of the day from certain standard locations, as follows:

Names of places at which Ringelmann chart readings were taken

Smoke of railroad origin:
1. East and west bound Baltimore & Ohio yards, East Grafton.
2. Yards in the proximity of the business and residence district, locomotives.
3. Baltimore & Ohio shops, eight stacks.
4. Baltimore & Ohio roundhouse, 21 jacks.

Smoke of nonrailroad origin:
1. Royal Window Glass Co., two stacks.
2. Crystal Ice Co., two stacks.
3. West Vrginia & Maryland Power Co., three stacks.
4. Home Laundry, one stack.

Readings were based on the standard Ringelmann chart system adopted by the United States Geological Survey and used by the Bureau of Mines. This system classifies smoke into five densities, Nos. 1, 2, 3, 4, and 5; When viewed directly across the stack, No. 1 smoke is 20 per cent dense; No. 2, 40 per cent; No. 3, 60 per cent; No. 4, 80 per cent; and No. 5, 100 per cent. Readings were taken every 15 seconds and the result of the observations was reduced to smoke-density figures by the formula:

$$\frac{\text{Equivalent units of No. 1 smoke} \times 20}{\text{Number of observations} \times 4} = \text{Per cent smoke density.}$$

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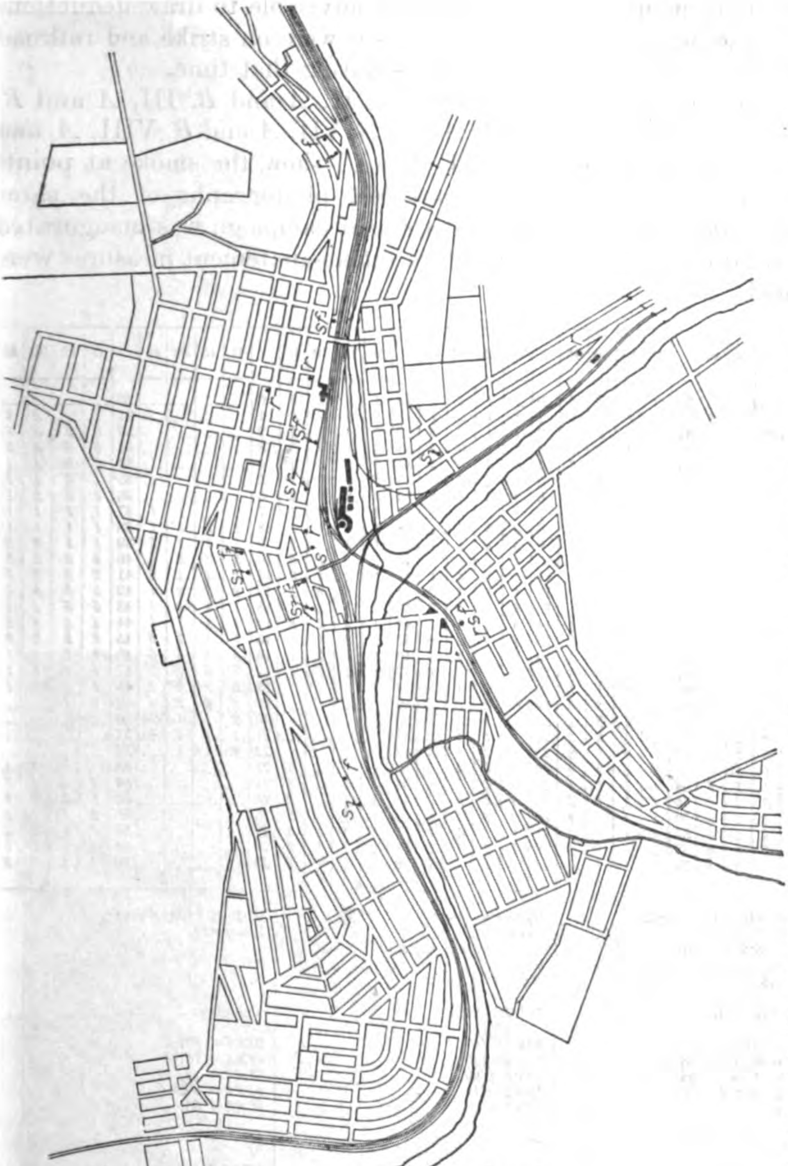


FIGURE 1.—Map of Grafton and vicinity showing where readings were taken: *f*, atmospheric filtration locations; *r*, Ringelmann observation points; *s*, soot-fall locations

Results of these observations are shown covering various hours of the day by months. The figures obtained during the first three months only are used for making comparisons. Although routine determinations of density and other items were continued throughout the summer months, it is not thought advisable to draw deductions from these figures as railroad employees were on strike and railroad operation was not on a normal basis during that time.

The accompanying illustrations (Pl. II, *A* and *B*, III, *A* and *B*, IV, *A* and *B*, V, *A* and *B*, VI, *A* and *B*, VII, *A* and *B*, VIII, *A* and *B*, IX, *A* and *B*, X, *A* and *B*, XI, *A* to *C*) show the smoke at points named in the tables. When possible, photographs of the same locality taken after the smoke-abatement campaign was inaugurated are placed beside those taken before smoke-abatement measures were adopted.

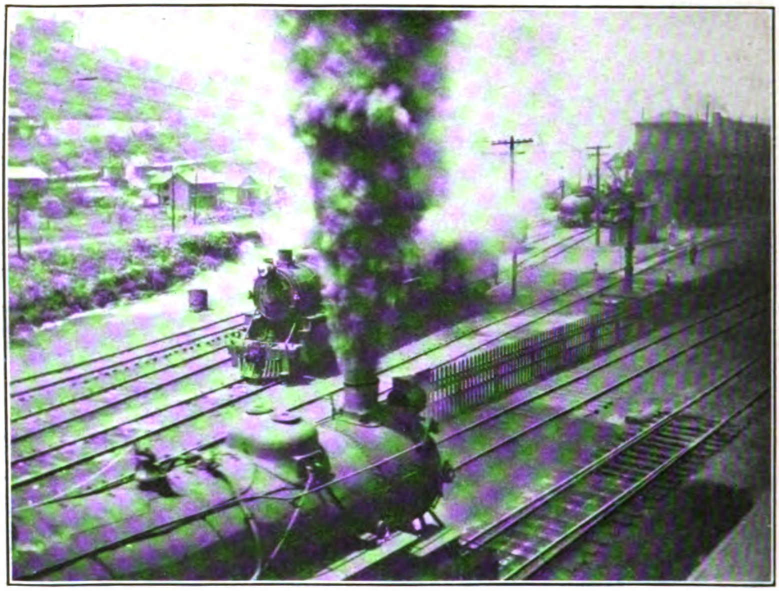
	0	15	30	45		0	15	30	45		0	15	30	45		0	15	30	45		0	15	30	45		0	15	30	45
0	---	---	---	---	30	*3*	*3*	*2*	*2*	0	*1*	*1*	*1*	*1*	30	*1*	*1*	*1*	*5*	0	---	---	---	---	30	---	---	---	---
1	---	---	*3*	*3*	31	*2*	*2*	*2*	*1*	1	*1*	*1*	*1*	*1*	31	*5*	*5*	*5*	*5*	1	---	---	---	---	31	---	---	*2*	*2*
2	*3*	*3*	*4*	*4*	32	*1*	*1*	*1*	*1*	2	*1*	*1*	*2*	*2*	32	*5*	*5*	*4*	*4*	2	---	---	---	---	32	*2*	*2*	*5*	*5*
3	*4*	*4*	*2*	*2*	33	*1*	*1*	*1*	*1*	3	*2*	*2*	*5*	*5*	33	*4*	*4*	*3*	*3*	3	---	---	---	---	33	*5*	*5*	*5*	*5*
4	*2*	*2*	*2*	*5*	34	*1*	*1*	*3*	*3*	4	*5*	*5*	*5*	*4*	34	*3*	*3*	*3*	*3*	4	---	---	---	---	34	*5*	*5*	*4*	*4*
5	*5*	*5*	*5*	*5*	35	*3*	*3*	*2*	*2*	5	*4*	*4*	*4*	*3*	35	*3*	*3*	*3*	*3*	5	---	---	---	---	35	*4*	*4*	*4*	*2*
6	*5*	*5*	*5*	*5*	36	*2*	*2*	*5*	*5*	6	*3*	*3*	*3*	*2*	36	*3*	*3*	*2*	*2*	6	---	---	---	---	36	*2*	*2*	*2*	*1*
7	*5*	*5*	*4*	*4*	37	*5*	*5*	*2*	*2*	7	*2*	*2*	*2*	*3*	37	*2*	*2*	*2*	*1*	7	---	---	*1*	*1*	37	*1*	*1*	*1*	*1*
8	*4*	*4*	*4*	*4*	38	*2*	*1*	*1*	*1*	8	*3*	*3*	*4*	*4*	38	*1*	*1*	*1*	*1*	8	*1*	*1*	*1*	*1*	38	*1*	*1*	*1*	*1*
9	*4*	*4*	*3*	*3*	39	*1*	*1*	*1*	*1*	9	*4*	*4*	*4*	*1*	39	*1*	*1*	*1*	*1*	9	*1*	*1*	*1*	*3*	39	*1*	*1*	*2*	*2*
10	*3*	*3*	*2*	*2*	40	*1*	*1*	---	---	10	*1*	*1*	*1*	*1*	40	*1*	*1*	*1*	*2*	10	*3*	*3*	*3*	*4*	40	*2*	*2*	*2*	*3*
11	*2*	*2*	*1*	*1*	41	---	---	---	---	11	*1*	*1*	*1*	*1*	41	*2*	*2*	*2*	*2*	11	*4*	*4*	*4*	*2*	41	*3*	*3*	*3*	*5*
12	*1*	*1*	*1*	*1*	42	---	---	---	---	12	*1*	*1*	*3*	*3*	42	*2*	*2*	*2*	*4*	12	*2*	*2*	*2*	*1*	42	*5*	*5*	*5*	*5*
13	*1*	*1*	*1*	*1*	43	---	---	---	---	13	*3*	*3*	*5*	*5*	43	*4*	*4*	*4*	*4*	13	*1*	*1*	*1*	*1*	43	*5*	*5*	*4*	*4*
14	*1*	*1*	---	---	44	*3*	*3*	*4*	*4*	14	*5*	*5*	*5*	*4*	44	*4*	*4*	*2*	*2*	14	*1*	*1*	*1*	*1*	44	*4*	*4*	*2*	*2*
15	---	---	---	---	45	*4*	*4*	*5*	*5*	15	*4*	*4*	*4*	*2*	45	*2*	*2*	*1*	*1*	15	*1*	*1*	*1*	*5*	45	*2*	*2*	*2*	*2*
16	---	---	---	---	46	*5*	*5*	*5*	*4*	16	*2*	*2*	*2*	*2*	46	*1*	*1*	*1*	*1*	16	*5*	*5*	*5*	*5*	46	*2*	*2*	*1*	*1*
17	---	---	*2*	*2*	47	*4*	*4*	*3*	*3*	17	*2*	*2*	*2*	*4*	47	*1*	*1*	*1*	*1*	17	*5*	*5*	*5*	*3*	47	*1*	*1*	*1*	*1*
18	*2*	*4*	*4*	*4*	48	*1*	*1*	*1*	*1*	18	*4*	*4*	*4*	*3*	48	*1*	*1*	*1*	---	18	*3*	*3*	*3*	*2*	48	*1*	*1*	*1*	*1*
19	*4*	*4*	*4*	*4*	49	*1*	*1*	*5*	*5*	19	*3*	*2*	*2*	*1*	49	---	---	---	---	19	*2*	*2*	*2*	*1*	49	*1*	*1*	---	---
20	*4*	*3*	*3*	*3*	50	*5*	*5*	*5*	*4*	20	*1*	*1*	*1*	*1*	50	---	---	---	---	20	*1*	*1*	*1*	*1*	50	---	---	---	---
21	*3*	*2*	*2*	*2*	51	*4*	*4*	*3*	*3*	21	*1*	*1*	*1*	*2*	51	---	---	---	---	21	*1*	*1*	*1*	*1*	51	---	---	---	---
22	*2*	*2*	*1*	*1*	52	*3*	*2*	*2*	*2*	22	*2*	*2*	*5*	*5*	52	---	---	---	---	22	*1*	*1*	*1*	---	52	---	---	---	---
23	*1*	*1*	*1*	*1*	53	*2*	*2*	*2*	*1*	23	*5*	*5*	*5*	*5*	53	---	---	*4*	*5*	23	---	---	---	---	53	---	---	*2*	*4*
24	*1*	*1*	*1*	*3*	54	*1*	*1*	*1*	*1*	24	*5*	*4*	*4*	*5*	54	*5*	*5*	*4*	*4*	24	---	---	---	---	54	*4*	*4*	*4*	*3*
25	*3*	*3*	*2*	*2*	55	*1*	*1*	*1*	*1*	25	*5*	*5*	*2*	*2*	55	*4*	*4*	*2*	*2*	25	---	---	---	---	55	*3*	*3*	*2*	*2*
26	*2*	*2*	*2*	*4*	56	*1*	*1*	*1*	*1*	26	*2*	*2*	*2*	*1*	56	*2*	*2*	*3*	*3*	26	---	---	---	---	56	*2*	*2*	*2*	*2*
27	*4*	*4*	*4*	*5*	57	*1*	*1*	*1*	*1*	27	*1*	*1*	*1*	*1*	57	*3*	*3*	*3*	*2*	27	---	---	---	---	57	*2*	*2*	*2*	*4*
28	*5*	*5*	*5*	*5*	58	*1*	*1*	*1*	*1*	28	*1*	*1*	*1*	*1*	58	*2*	*2*	*2*	*2*	28	---	---	---	---	58	*4*	*5*	*5*	*5*
29	*5*	*3*	*3*	*3*	59	*1*	*1*	*1*	*1*	29	*1*	*1*	*1*	*1*	59	*2*	*2*	*2*	*2*	29	---	---	---	---	59	*5*	*5*	*5*	*5*

Plant: *Opposite depot.*	*Opposite shops.*	*Opposite roundhouse.*
Stack: *7 engines.*	*7 engines.*	*3 engines.*
Observation point.	*Archdeacon's store.*	
Feet from stack: *1,200.*	*800.*	*200.*
Direction of stack: *SE.*	*SE.*	*S.*
Weather: *Clear.*	Wind: *SW.*	Velocity: *4.*
No. 5—*31×5=155.*	*30×5=150.*	*30×5=150.*
No. 4—*34×4=136.*	*35×4=140.*	*19×4= 76.*
No. 3—*31×3= 93.*	*30×3= 90.*	*15×3= 45.*
No. 2—*40×2= 80.*	*56×2=112.*	*40×2= 80.*
No. 1—*72×1= 72.*	*70×1= 70.*	*56×1= 56.*
Units No. 1—*536.*	*562.*	*407.*
$\frac{536\times.20}{60\times.4}$=44 per cent.	$\frac{562\times.20}{60\times.4}$=46 per cent.	$\frac{407\times.20}{60\times.4}$=33.91 per cent.
Remarks: ----------	----------	----------
	Time: *11 to 12.*	Date: *June 26, 1922.*

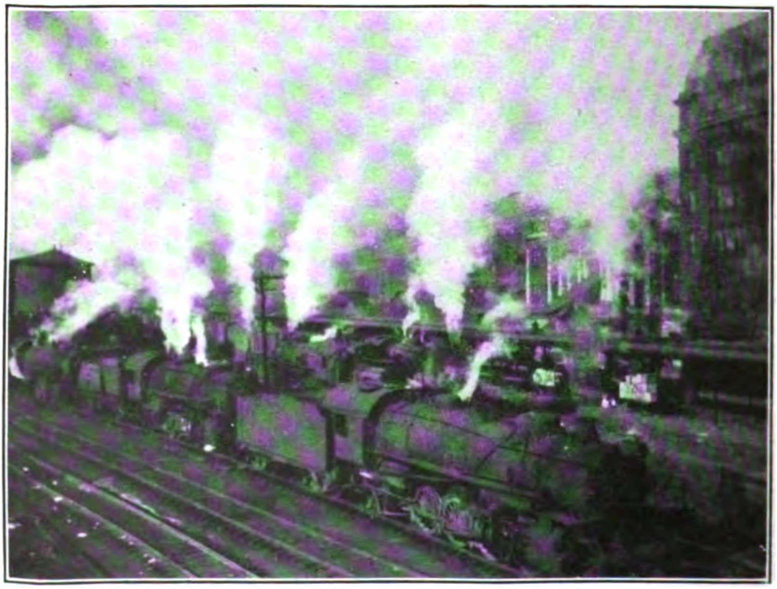
FIGURE 2.—Record of Ringelmann readings, locomotives, June 26, 1922

A. SMOKE CLOUD FORMING IN RAILROAD YARDS AND DRIFTING NORTHEAST OVER MAIN STREET

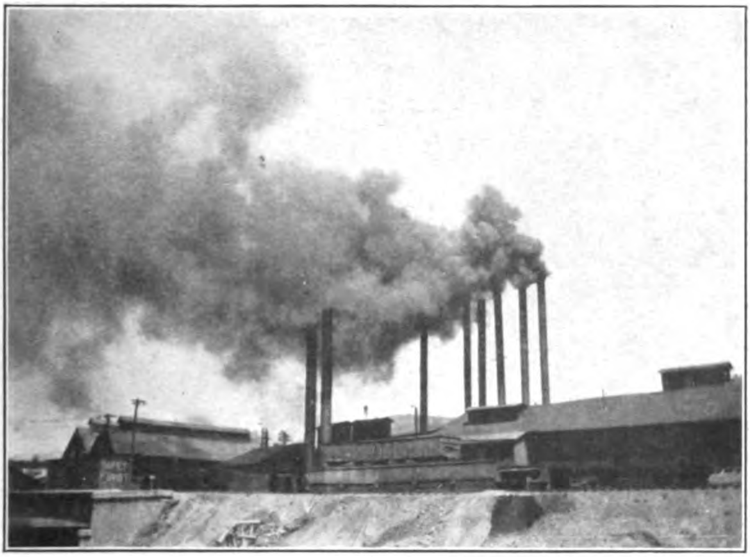
B. SMOKE OBSCURING SUN, APRIL 13



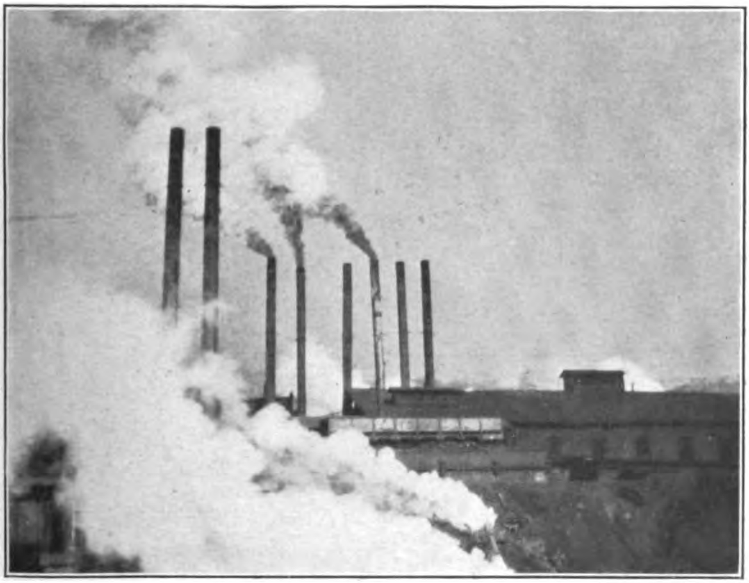
A. ENGINE OPPOSITE DEPOT, JUNE 12



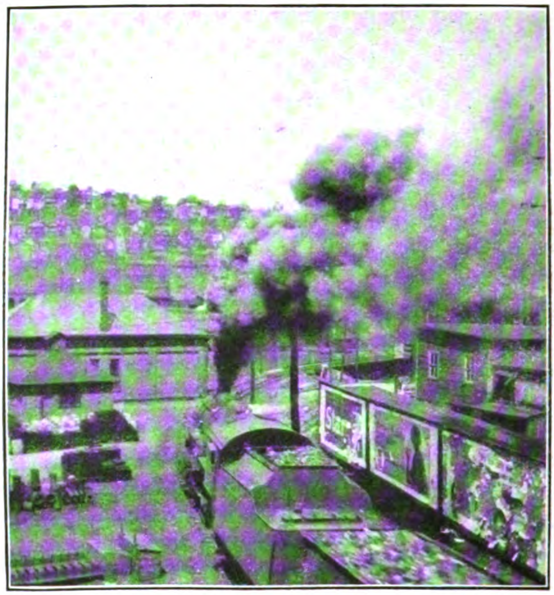
B. ENGINES IN YARD OPPOSITE DEPOT, DECEMBER 19



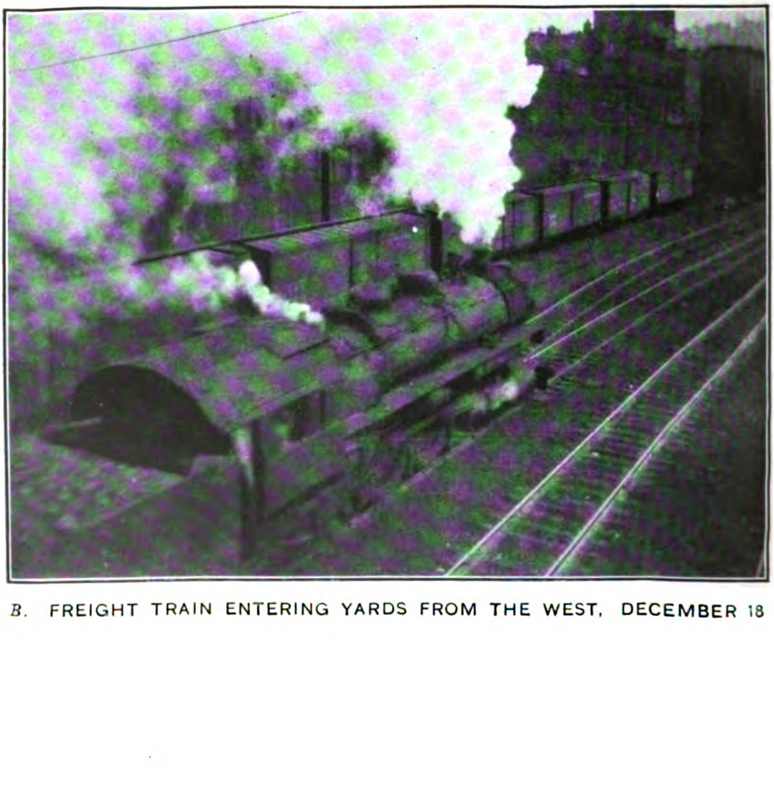
A. SHOPS, LOOKING NORTHWEST, JUNE 2



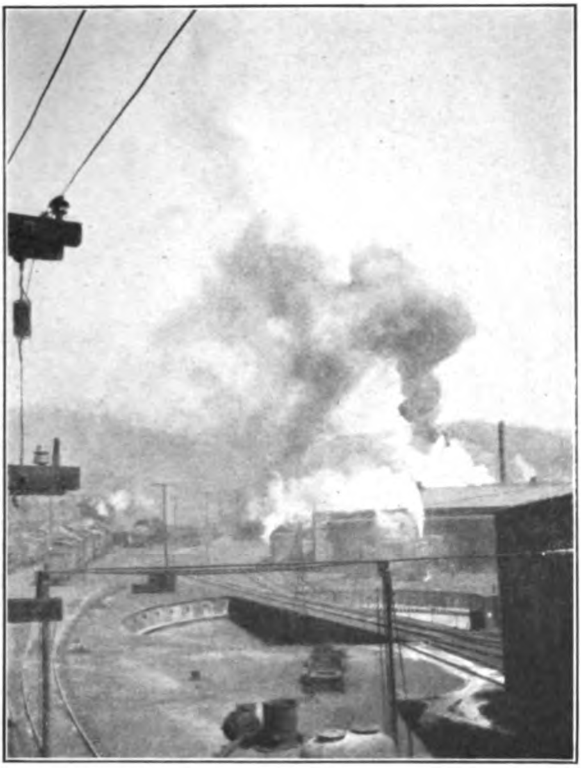
B. SHOPS, LOOKING NORTH, DECEMBER 19



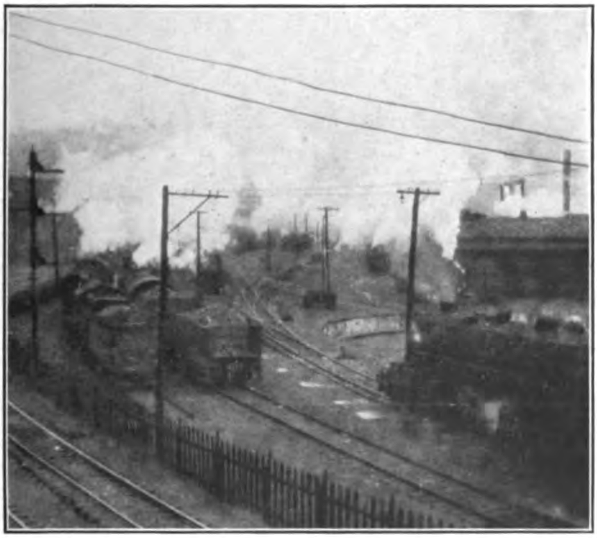
A. COAL TRAIN ENTERING GRAFTON FROM THE SOUTH, APRIL 17



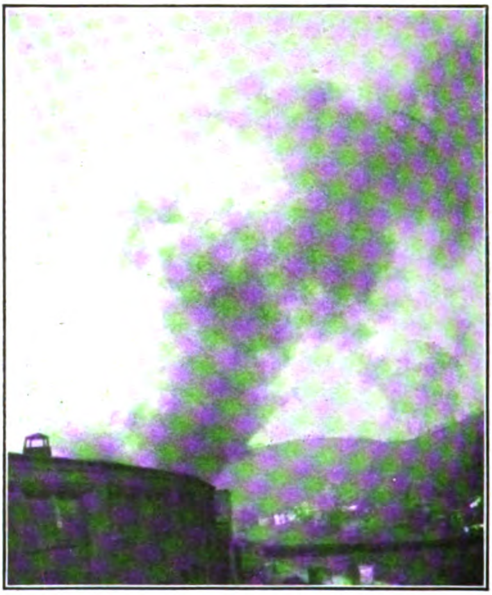
B. FREIGHT TRAIN ENTERING YARDS FROM THE WEST, DECEMBER 18



A. YARDS AND SHOPS, LOOKING SOUTHEAST, APRIL 17

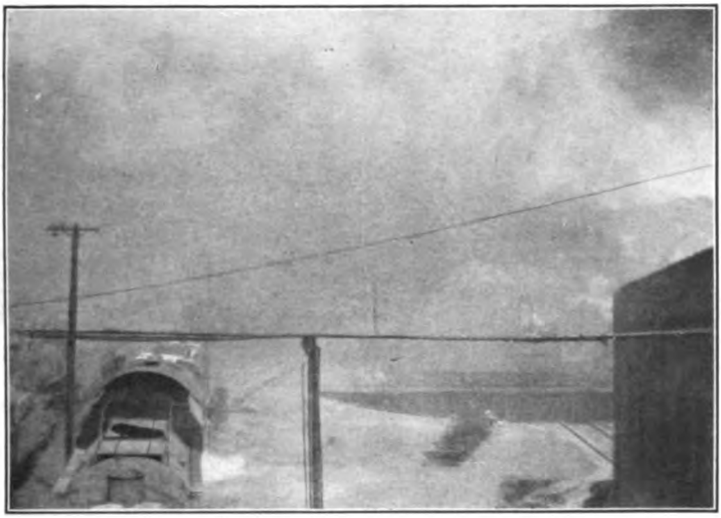


B. YARDS AND SHOPS, LOOKING EAST, DECEMBER 19

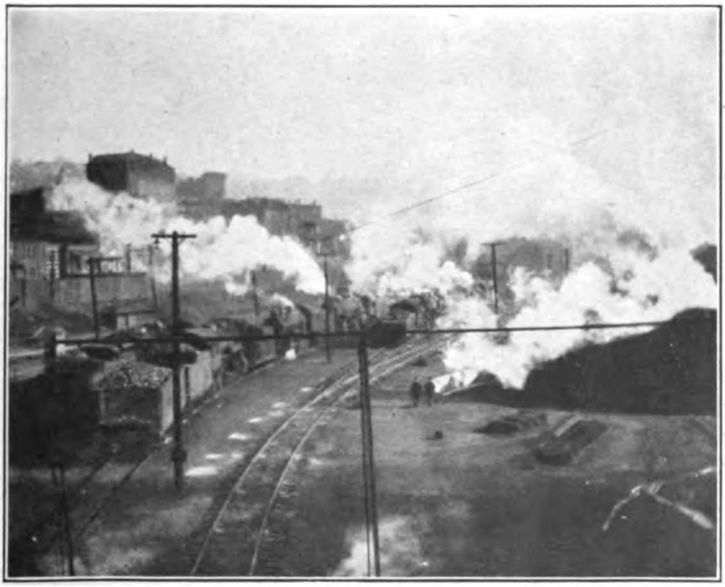


A. ROUNDHOUSE FROM BRIDGE, LOOKING SOUTHEAST, APRIL 15

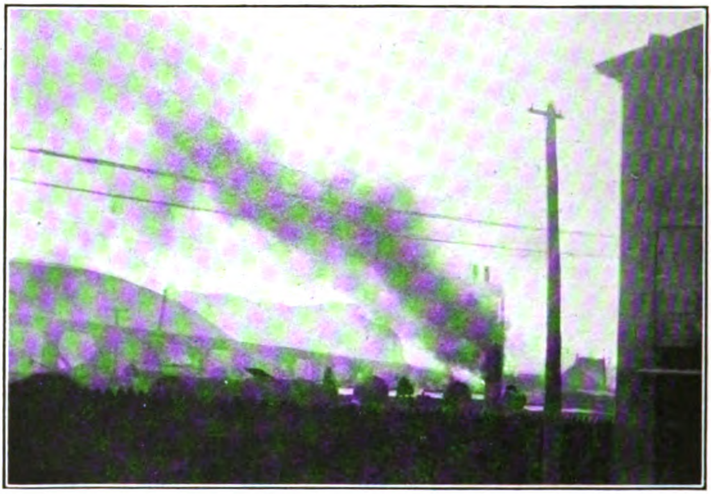
B. ROUNDHOUSE, LOOKING NORTHEAST, DECEMBER 18



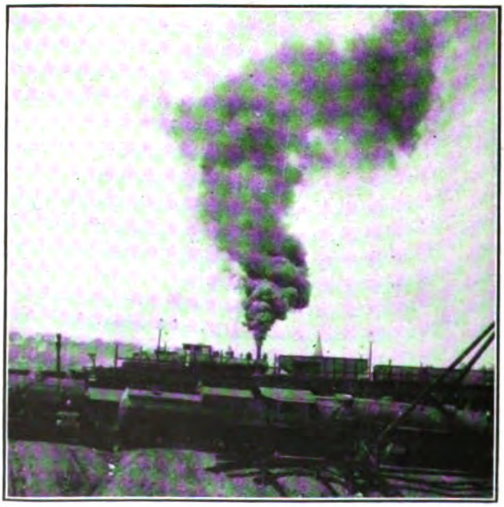
A. YARDS, LOOKING EAST FROM ROUNDHOUSE, APRIL 17



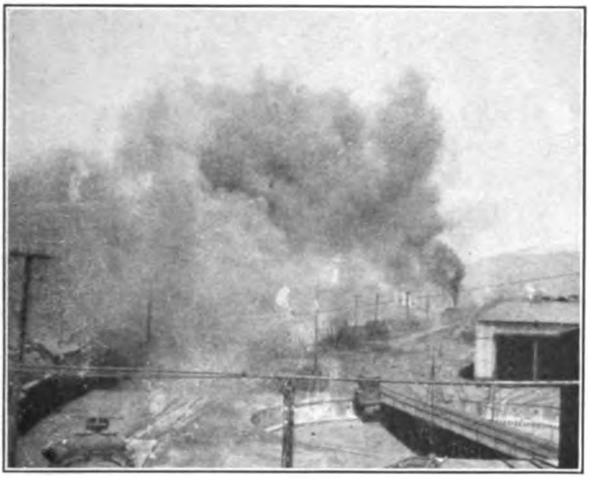
B. YARDS, LOOKING EAST, DECEMBER 18



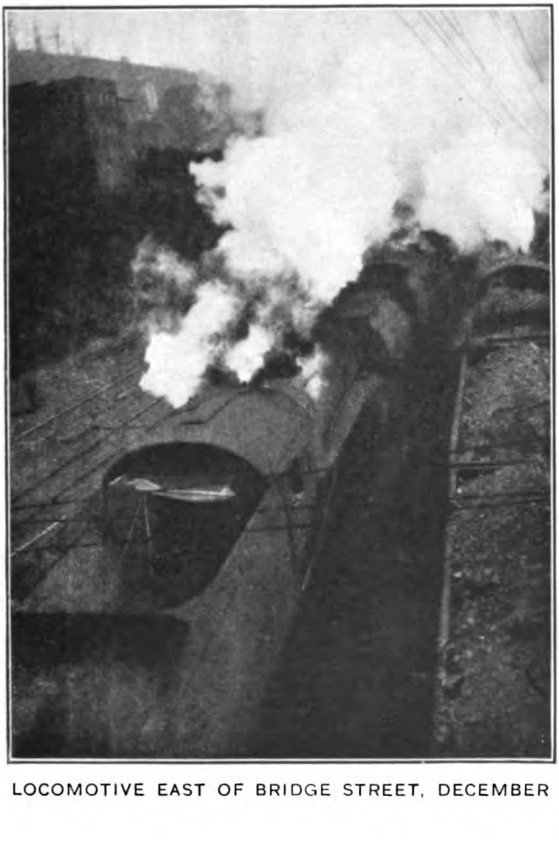
A. LOCOMOTIVE AT FOOT OF ST. JOHN STREET, MAY 13



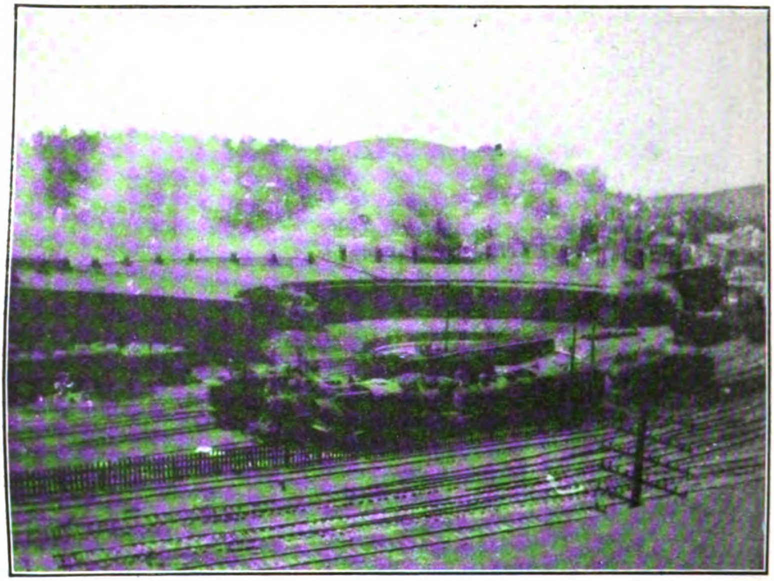
B. LOCOMOTIVE AT COAL TIPPLE, JUNE 2



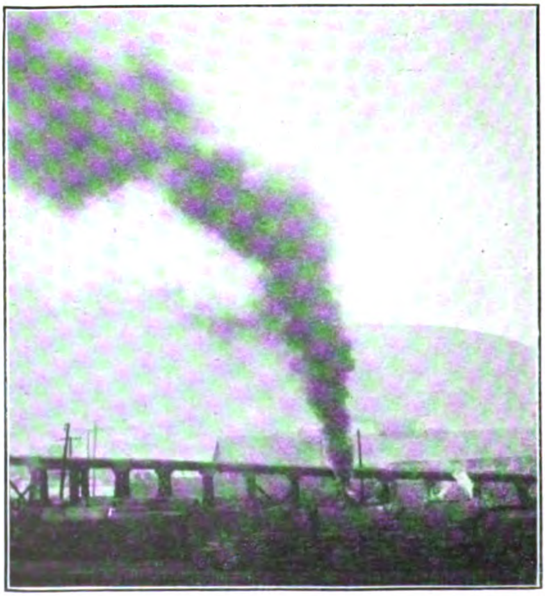
A. LOCOMOTIVE PASSING UNDER BRIDGE STREET, JUNE 7



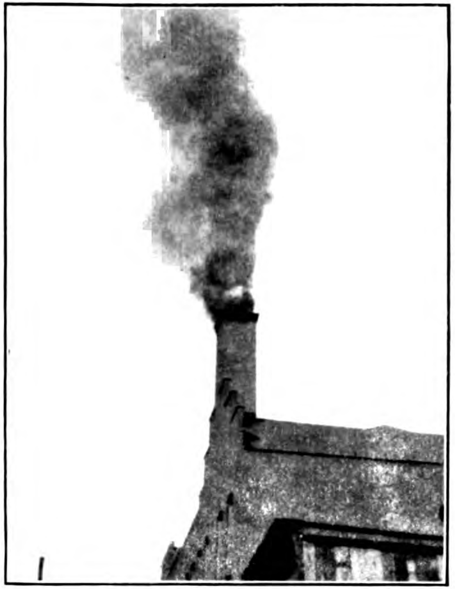
B. LOCOMOTIVE EAST OF BRIDGE STREET, DECEMBER 18



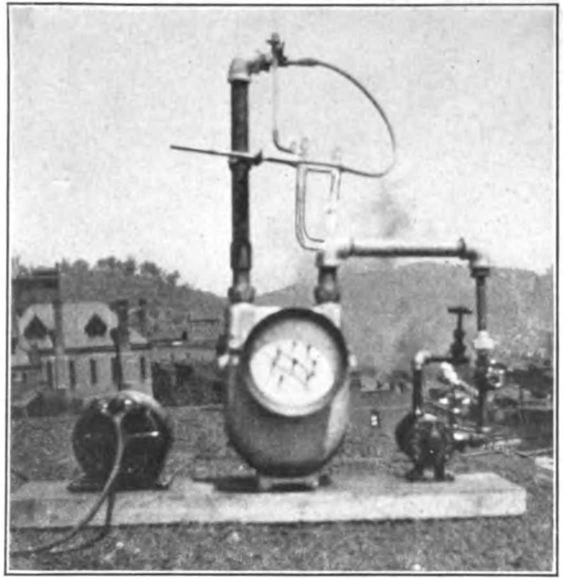
A. ROUNDHOUSE FROM ARCHDEACON'S STORE, JUNE 14



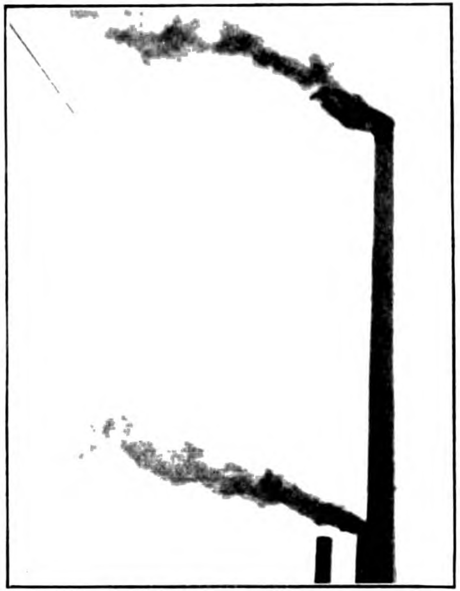
B. LOCOMOTIVE OPPOSITE COHEN'S STORE, JUNE 13



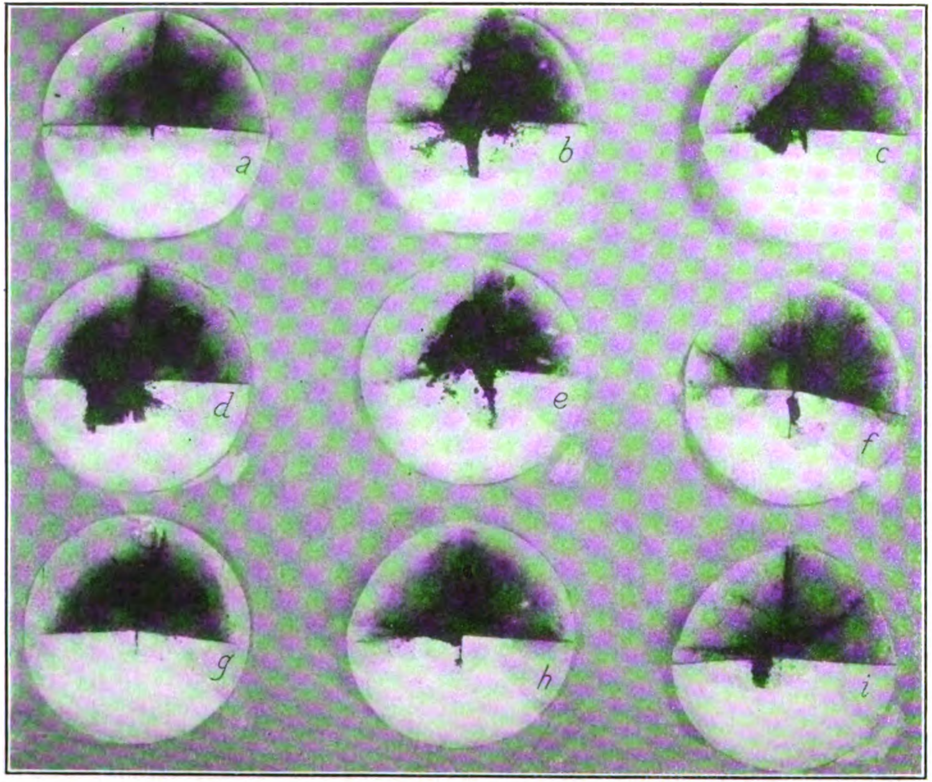
A. STACKS OF HOME LAUNDRY



B. FILTRATION APPARATUS IN OPERATION

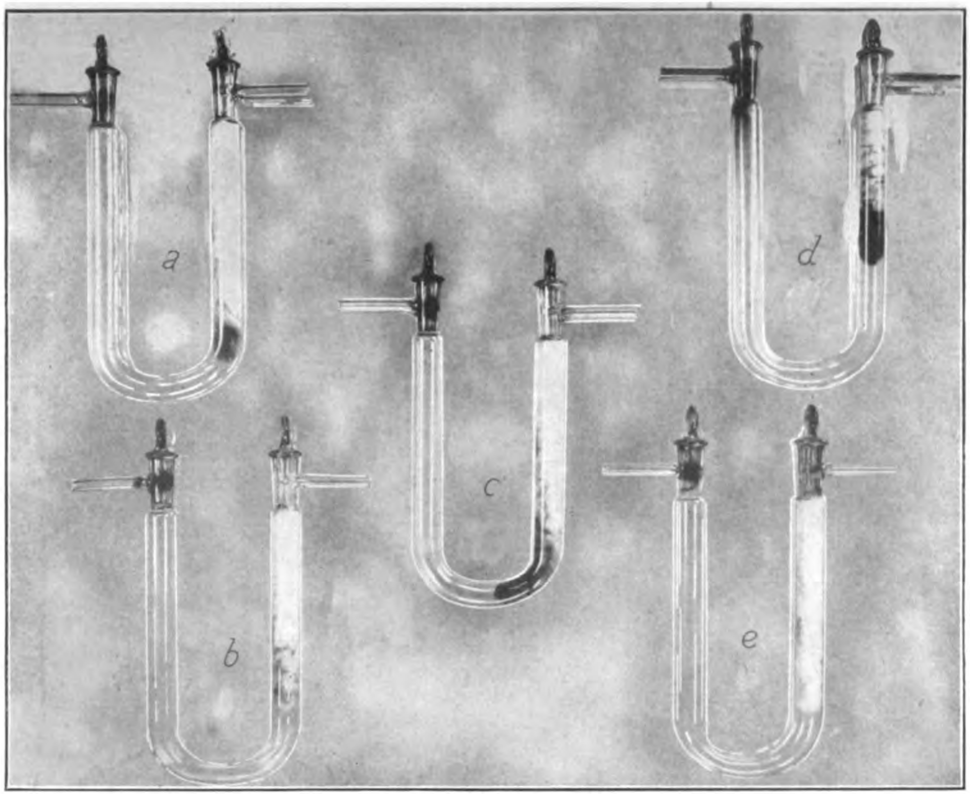


C. STACKS OF WEST VIRGINIA-MARYLAND POWER CO., APRIL 22



SOOT FALL TAKEN FROM: *a*, LINCOLN STREET; *b* COMPTON'S GARAGE; *c*, COHEN'S STORE; *d*, HENDRICKSON'S STORE; *e*, SENTINEL BUILDING; *f*, HIGH SCHOOL; *g*, 427 WEST MAIN STREET; *h*, ACME ICE CREAM BUILDING; *i*, 211 GRAND AVENUE

Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN



ATMOSPHERIC FILTERS FROM: *a*, COMPTON'S GARAGE; *b*, HIGH SCHOOL; *c*, COHEN'S STORE; *d*, POST OFFICE; *e*, 415 WEST MAIN STREET

	0	15	30	45		0	15	30	45		0	15	30	45		0	15	30	45		0	15	30	45		0	15	30	45
0	3	3	4	5	30	3	2	2	1	0					30					0	1	1	3	5	30				
1	5	5	5	5	31	1	1	1		1			2	5	31					1	5	5	5	5	31				
2	5	5	5	4	32					2	5	5	5	5	32					2	5	5	5	4	32	3	4	5	5
3	4	4	4	3	33					3	5	5	5	5	33					3	4	4	4	4	33	5	5	5	5
4	3	3	3	3	34					4	5	4	4	3	34					4	4	3	3	2	34	5	5	5	4
5	3	2	2	1	35					5	3	3	2	1	35					5	2	2	1	1	35	3	3	2	2
6	1	1	1	1	36					6	1	1	1	1	36					6	1	1	1	1	36	2	1	1	1
7	1	1	1	1	37					7	1	1	1	1	37					7	1	1			37	1	1	1	1
8	1	1			38					8	1				38					8					38	1			
9					39					9					39					9					39				
10					40					10					40					10					40				
11					41					11					41					11					41				
12					42					12					42					12			3	5	42				
13			3	4	43			3	4	13					43					13	5	5	5	4	43				
14	5	5	5	4	44	5	5	5	5	14					44				4	14	4	4	4	3	44				
15	4	4	3	3	45	5	5	5	5	15					45	5	5	5	5	15	3	3	2	1	45				
16	3	3	2	1	46	5	4	3	3	16					46	5	5	5	5	16	1	1	1		46			3	3
17	1	1	1	1	47	3	2	2	2	17					47	5	5	5	4	17					47	5	5	5	5
18	1	1			48	2	1	1	1	18					48	3	3	2	2	18					48	5	5	5	5
19					49	1	1	1	1	19					49	1	1	1	1	19				3	49	4	3	3	2
20					50	1	1	1	1	20					50	1	1			20	4	5	5	5	50	2	1	1	1
21					51	1	1	1	1	21					51					21	5	5	5	5	51	1	1	1	1
22			4	4	52					22					52					22	5	5	4	3	52				
23	5	5	5	5	53					23					53					23	2	2	2	2	53				
24	5	5	5	5	54					24				3	54					24	2	1	1	1	54				
25	5	5	5	5	55					25	4	5	5	5	55					25	1	1	1		55				
26	5	5	5	5	56					26	5	5	5	5	56					26					56				
27	5	5	5	5	57					27	3	3	2	1	57			2	2	27					57			3	3
28	5	5	5	5	58					28	1	1	1	1	58	3	5	5	5	28					58	4	5	5	5
29	5	5	5	4	59					29	1				59	5	5	5	5	29					59	5	5	5	5

Plant: *West Va. & Maryland Power Co.*	*West Va. & Maryland Power Co.*	*Crystal Ice Co.*
Stack: *Tall*	*Small*	*Tall.*
Observation point	*Post Office*	
Feet from stack	*1,200*	*600.*
Direction of stack	*SE*	*SW.*
Weather: *Clear*	Wind: *SW*	Velocity *3.*
No. 5—*47×5=235*	*35×5=175*	*45×5=225.*
No 4—*13×4= 52*	*5×4= 20*	*16×4= 64.*
No. 3—*18×3= 54*	*9×3= 27*	*18×3= 54.*
No. 2— *9×2= 18*	*7×2= 14*	*14×2= 28.*
No. 1—*37×1= 37*	*22×1= 22*	*35×1= 35.*
Units No. 1— *396*	*258*	*406.*
$\frac{396\times.20}{60\times.4}$=*33 per cent*	$\frac{258\times.20}{60\times.4}$=*21.5 per cent*	$\frac{406\times.20}{60\times.4}$=*33.8 per cent.*
Remarks		
	Time: *3 to 4*	Date: *June 14, 1922.*

FIGURE 3.—Record of Ringelmann readings, industrial plants, June 14, 1922

TABLE 1.—*Ringelmann chart readings for April, giving hourly averages in per cent*

Royal Window Glass Co.		**East and west bound Baltimore & Ohio yards**	
8 to 9	28.95	8 to 9	48.70
9 to 10	21.71	9 to 10	63.75
10 to 11	32.25	10 to 11	43.66
11 to 12	24.77	11 to 12	57.70
1 to 2	14.16	1 to 2	59.66
2 to 3	18.58	2 to 3	19.66
3 to 4	24.16	3 to 4	34.33
4 to 5	25.46	4 to 5	32.60
Daily average	23.75	Daily average	45.01

Table 1.—*Ringelmann chart readings for April, giving hourly average in per cent*—Concluded

Baltimore & Ohio yards near business district					
Opposite depot		Opposite shops		Opposite roundhouse	
8 to 9	44.33	8 to 9	41.70	8 to 9	15.41
9 to 10	64.74	9 to 10	41.49	9 to 10	25.08
10 to 11	46.08	10 to 11	49.33	10 to 11	24.00
11 to 12	38.66	11 to 12	22.58	11 to 12	16.00
1 to 2	45.95	1 to 2	52.12	1 to 2	56.41
2 to 3	29.26	2 to 3	17.75	2 to 3	16.33
3 to 4	49.16	3 to 4	31.66	3 to 4	33.83
4 to 5	59.37	4 to 5	44.62	4 to 5	16.54
Daily average	47.18	Daily average	37.65	Daily average	25.70

Baltimore & Ohio shops					
Stacks 1 and 2		Stacks 3 and 4		Stack 5	
8 to 9	39.24	8 to 9	26.28	8 to 9	37.40
9 to 10	23.99	9 to 10	29.99	9 to 10	46.41
10 to 11	30.62	10 to 11	33.85	10 to 11	33.61
11 to 12	23.45	11 to 12	33.58	11 to 12	25.83
1 to 2	26.41	1 to 2	30.75	1 to 2	37.50
2 to 3	36.99	2 to 3	47.49	2 to 3	44.66
3 to 4	18.08	3 to 4	23.91	3 to 4	29.85
4 to 5	31.08	4 to 5	35.12	4 to 5	50.53
Daily average	28.72	Daily average	32.62	Daily average	38.19

West Virginia & Maryland Power Co.				Crystal Ice Co.	
Large stack		Small stack		Two stacks	
8 to 9	32.28	8 to 9	17.29	8 to 9	24.45
9 to 10	21.54	9 to 10	12.78	9 to 10	21.99
10 to 11	28.04	10 to 11	12.33	10 to 11	24.08
11 to 12	24.75	11 to 12	16.37	11 to 12	24.12
1 to 2	26.18	1 to 2	12.00	1 to 2	31.08
2 to 3	34.54	2 to 3	27.00	2 to 3	30.95
3 to 4	30.91	3 to 4	21.45	3 to 4	32.49
4 to 5	35.91	4 to 5	17.00	4 to 5	37.16
Daily average	29.26	Daily average	17.02	Daily average	28.29

Baltimore & Ohio roundhouse, 21 jacks [a]							
8 to 9		9 to 10		10 to 11		11 to 12	
No. 1	9.75	No. 13	48.41	No. 9	15.83	No. 4	14.83
No. 2	30.25	No. 6	9.00	No. 6	26.12	No. 5	4.75
No. 3	8.25	No. 4	12.41	No. 3	19.75	No. 20	21.91
No. 6	8.83	No. 10	6.66	No. 10	19.25	No. 6	30.25
No. 7	9.75					No. 7	14.33
						No. 10	13.50
1 to 2		2 to 3		3 to 4		4 to 5	
No. 17	7.58	No. 10	20.66	No. 4	40.35	No. 9	65.41
No. 20	11.41	No. 11	9.83	No. 7	44.00	No. 17	17.16
No. 3	15.08	No. 16	6.66	No. 15	8.41	No. 16	35.25
No. 8	57.25			No. 21	9.16		
No. 7	47.75			No. 2	43.75		
				No. 1	53.33		
				No. 3	40.00		

[a] Gives hourly average for each jack.

TABLE 2.—*Ringelmann chart readings for May, giving hourly averages in per cent*

Royal Window Glass Co.				**East and west bound Baltimore & Ohio yards**	
Large stack		Small stack		Locomotives	
8 to 9	9.25	8 to 9	24.87	8 to 9	40.08
9 to 10	8.00	9 to 10	19.58	9 to 10	62.33
10 to 11	10.33	10 to 11	25.75	10 to 11	44.41
11 to 12	10.41	11 to 12	24.25	11 to 12	50.08
1 to 2	8.08	1 to 2	27.54	1 to 2	47.90
2 to 3	8.75	2 to 3	25.83	2 to 3	40.00
3 to 4	8.58	3 to 4	22.08	3 to 4	40.33
4 to 5	8.00	4 to 5	29.83	4 to 5	32.91
Daily average	8.92	Daily average	24.96	Daily average	44.75
Baltimore & Ohio yards near business district					
Opposite depot		Opposite shops		Opposite roundhouse	
8 to 9	48.24	8 to 9	39.75	8 to 9	31.91
9 to 10	27.79	9 to 10	50.83	9 to 10	50.87
10 to 11	42.36	10 to 11	46.38	10 to 11	46.78
11 to 12	59.02	11 to 12	29.41	11 to 12	33.94
1 to 2	37.16	1 to 2	37.41	1 to 2	23.33
2 to 3	51.16	2 to 3	57.66	2 to 3	48.20
3 to 4	52.75	3 to 4	22.66	3 to 4	28.41
4 to 5	42.50	4 to 5	47.50	4 to 5	36.33
Daily average	45.12	Daily average	42.67	Daily average	37.47
Baltimore & Ohio shops					
Stacks 1 and 2		Stacks 3 and 4		Stack 5	
8 to 9	47.94	8 to 9	46.66	8 to 9	46.77
9 to 10	42.08	9 to 10	34.60	9 to 10	46.16
10 to 11	34.86	10 to 11	38.05	10 to 11	42.13
11 to 12	37.16	11 to 12	38.00	11 to 12	36.79
1 to 2	30.91	1 to 2	34.91	1 to 2	38.83
2 to 3	39.78	2 to 3	40.12	2 to 3	32.83
3 to 4	16.25	3 to 4	17.44	3 to 4	33.19
4 to 5	42.50	4 to 5	26.83	4 to 9	29.25
Daily average	34.74	Daily average	34.57	Daily average	38.24
West Virginia & Maryland Power Co.				**Crystal Ice Co.**	
Large stack		Small stack		Two stacks	
8 to 9	37.70	8 to 9	23.41	8 to 9	31.95
9 to 10	30.61	9 to 10	21.52	9 to 10	29.70
10 to 11	34.25	10 to 11	22.03	10 to 11	26.37
11 to 12	26.10	11 to 12	16.52	11 to 12	24.13
1 to 2	36.66	1 to 2	29.04	1 to 2	25.99
2 to 3	37.66	2 to 3	23.08	2 to 3	32.75
3 to 4	43.53	3 to 4	21.04	3 to 4	28.53
4 to 5	28.24	4 to 5	21.45	4 to 5	26.82
Daily average	34.30	Daily average	22.26	Daily average	28.28

TABLE 2.—*Ringelmann chart readings for May, giving hourly averages in per cent*—Concluded

Baltimore & Ohio roundhouse, 21 jacks[a]

8 to 9	9 to 10	10 to 11	11 to 12
No. 14 ... 17. 08 No. 9 ... 27. 28 No. 21 ... 17. 16 No. 6 ... 25. 33	No. 11 ... 15. 04 No. 13 ... 14. 50 No. 17 ... 28. 08	No. 14 ... 13. 25 No. 16 ... 7. 16 No. 9 ... 16. 08 No. 5 ... 25. 41	No. 10 .. 23. 50 No. 19 .. 13. 91 No. 21 .. 37. 25 No. 14 .. 16. 16 No. 11 .. 25. 33 No. 17 .. 22. 66
1 to 2	**2 to 3**	**3 to 4**	**4 to 5**
No. 9 ... 52. 25 No. 5 ... 11. 25 No. 21 ... 14. 58 No. 18 ... 19. 50	No. 4 ... 7. 41 No. 15 ... 12. 33 No. 17 ... 7. 33 No. 8 ... 21. 50 No. 11 ... 56. 50 No. 9 ... 23. 75	No. 5 ... 25. 00 No. 14 ... 20. 66	No. 6 ... 13. 91 No. 11 .. 10. 41 No. 7 ... 14. 16 No. 10 .. 24. 25 No. 17 .. 11. 33

[a] Gives hourly average for each jack.

TABLE 3.—*Ringelmann chart readings for June, giving hourly averages in per cent*

Baltimore & Ohio yards near business district

Opposite depot		Opposite shops		Opposite roundhouse	
8 to 9	52. 05	8 to 9	34. 35	8 to 9	28. 47
9 to 10	41. 61	9 to 10	41. 60	9 to 10	25. 26
10 to 11	43. 99	10 to 11	37. 83	10 to 11	29. 72
11 to 12	46. 43	11 to 12	37. 16	11 to 12	31. 82
1 to 2	61. 25	1 to 2	48. 45	1 to 2	32. 79
2 to 3	38. 16	2 to 3	43. 13	2 to 3	30. 87
3 to 4	41. 95	3 to 4	38. 25	3 to 4	26. 50
4 to 5	51. 49	4 to 5	49. 12	4 to 5	34. 44
Daily average	47. 11	Daily average	41. 09	Daily average	30. 12

Baltimore & Ohio shops

Stack 3		Stack 4		Stack 5		Stack 1 and 2
8 to 9	34. 94	8 to 9	43. 08	8 to 9	40. 91	41. 72
9 to 10	31. 21	9 to 10	39. 22	9 to 10	43. 37	
10 to 11	34. 46	10 to 11	40. 58	10 to 11	57. 22	
11 to 12	31. 87	11 to 12	51. 46	11 to 12	59. 83	
1 to 2	41. 08	1 to 2	46. 95	1 to 2	50. 74	
2 to 3	44. 36	2 to 3	48. 10	2 to 3	56. 77	
3 to 4	32. 37	3 to 4	41. 53	3 to 4	49. 79	
4 to 5	31. 33	4 to 5	37. 04	4 to 5	42. 74	
Daily av.	35. 22	Daily av.	43. 49	Daily av.	50. 17	

Table 3.—*Ringelmann chart readings for June, giving hourly averages in per cent*—Concluded

West Virginia & Maryland Power Co.				Crystal Ice Co.	
Large stack		Small stack		Two stacks	
8 to 9	29. 63	8 to 9	20. 99	8 to 9	20. 33
9 to 10	28. 46	9 to 10	24. 46	9 to 10	29. 91
10 to 11	30. 25	10 to 11	16. 91	10 to 11	28. 51
11 to 12	33. 86	11 to 12	26. 61	11 to 12	32. 71
1 to 2	30. 75	1 to 2	21. 83	1 to 2	29. 91
2 to 3	33. 49	2 to 3	15. 41	2 to 3	33. 37
3 to 4	40. 55	3 to 4	23. 33	3 to 4	30. 37
4 to 5	31. 80	4 to 5	18. 35	4 to 5	28. 74
Daily average	33. 59	Daily average	20. 98	Daily average	29. 32

Baltimore & Ohio roundhouse, 21 jacks [a]

8 to 9		9 to 10		10 to 11		11 to 12	
No. 16	31. 00	No. 9	28. 12	No. 15	16. 00	No. 11	63. 08
No. 11	25. 33	No. 16	14. 33	No. 9	15. 33	No. 15	34. 75
No. 14	34. 41	No. 10	15. 33	No. 18	26. 66	No. 8	13. 16
		No. 18	23. 83	No. 16	38. 91		
				No. 10	18. 50		
				No. 13	37. 16		
				No. 21	44. 58		

1 to 2		2 to 3		3 to 4		4 to 5	
No. 10	36. 75	No. 2	22. 91	No. 6	9. 91	No. 9	36. 41
No. 11	33. 75	No. 10	26. 41	No. 10	57. 08	No. 18	26. 08
No. 15	36. 25	No. 16	40. 66	No. 21	16. 66	No. 10	28. 00
No. 20	32. 50	No. 18	39. 25	No. 20	39. 00		
		No. 13	33. 00				

Home Laundry

8 to 9	22. 08
9 to 10	22. 91
10 to 11	22. 78
11 to 12	20. 99
1 to 2	20. 45
2 to 3	29. 58
3 to 4	24. 37
4 to 5	22. 45
Daily average	23. 20

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[a] Gives hourly average for each jack.

Table 4.—*Ringelmann chart readings for July, giving hourly averages in per cent*

Baltimore & Ohio yards near business district					
Opposite depot		Opposite shops		Opposite roundhouse	
8 to 9	29.95	8 to 9	28.79	8 to 9	14.45
9 to 10	45.25	9 to 10	51.29	9 to 10	37.45
10 to 11	42.79	10 to 11	43.95	10 to 11	15.55
11 to 12	38.94	11 to 12	29.91	11 to 12	
1 to 2	41.83	1 to 2	39.33	1 to 2	12.08
2 to 3	41.37	2 to 3	18.83	2 to 3	31.16
3 to 4	27.49	3 to 4	42.54	3 to 4	15.16
4 to 5	27.20	4 to 5	24.62	4 to 5	
Daily average	36.85	Daily average	34.90	Daily average	15.73
Baltimore & Ohio shops					
Stacks 2 and 3		Stack 4		Stack 5	
8 to 9	31.24	8 to 9	30.75	8 to 9	26.95
9 to 10	32.69	9 to 10	27.41	9 to 10	30.67
10 to 11	21.38	10 to 11	19.63	10 to 11	23.44
11 to 12	36.50	11 to 12	29.16	11 to 12	20.83
1 to 2	33.24	1 to 2	26.08	1 to 2	28.70
2 to 3	20.95	2 to 3	22.54	2 to 3	27.33
3 to 4	36.58	3 to 4	29.95	3 to 4	25.62
4 to 5	33.83	4 to 5	23.54	4 to 5	30.75
Daily average	33.05	Daily average	26.13	Daily average	26.78
West Virginia & Maryland Power Co.				**Crystal Ice Co.**	
Large stack		Small stack		Two stacks	
8 to 9	29.74	8 to 9	25.96	8 to 9	32.08
9 to 10	33.47	9 to 10	20.66	9 to 10	26.74
10 to 11	21.19	10 to 11	20.33	10 to 11	25.33
11 to 12	21.33	11 to 12	16.95	11 to 12	30.66
1 to 2	34.08	1 to 2	22.41	1 to 2	37.91
2 to 3	34.25	2 to 3	25.83	2 to 3	29.20
3 to 4	34.66	3 to 4	25.37	3 to 4	32.46
4 to 5	25.83	4 to 5	21.16	4 to 5	25.33
Daily average	29.13	Daily average	22.33	Daily average	29.66

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Table 4.—*Ringelmann chart readings for July, giving hourly averages in per cent*—Concluded

Baltimore & Ohio roundhouse, 21 jacks[a]

8 to 9	9 to 10	10 to 11	11 to 12
No. 11 --- 31. 75 No. 16 --- 26. 33	No. 11 --- 28. 41 No. 19 --- 17. 58 No. 17 --- 72. 08	No. 3 ---- 26. 91 No. 7 ---- 27. 58 No. 6 ---- 13. 91 No. 16 --- 23. 83	No. 9 --- 32. 66 No. 17 -- 30. 00 No. 10 -- 34. 00
1 to 2	**2 to 3**	**3 to 4**	**4 to 5**
No. 10 --- 39. 41 No. 16 --- 24. 00	No. 9 ---- 37. 50 No. 16 --- 42. 08 No. 15 --- 40. 08 No. 18 --- 17. 58	No. 15 --- 40. 00 No. 6 ---- 31. 16 No. 16 --- 24. 50	No. 6 --- 47. 66 No. 15 -- 29. 12

Home Laundry

8 to 9	26. 25
9 to 10	21. 91
10 to 11	29. 54
11 to 12	36. 00
1 to 2	28. 08
2 to 3	30. 41
3 to 4	35. 80
4 to 5	33. 49
Daily average	30. 18

[a] Gives hourly average for each jack.

Table 5.—*Ringelmann chart readings for August, giving hourly averages in per cent*

Baltimore & Ohio yards near business district

	Opposite depot	Opposite shops	Opposite roundhouse
8 to 9	40. 39	46. 01	31. 28
9 to 10	36. 02	37. 36	32. 41
10 to 11	37. 95	31. 87	24. 87
11 to 12	36. 35	42. 14	24. 95
1 to 2	45. 41	40. 77	17. 77
2 to 3	43. 74	42. 71	30. 62
3 to 4	24. 45	43. 37	13. 79
4 to 5	32. 91	53. 58	37. 62
Daily average	37. 15	42. 22	26. 66

TABLE 5.—*Ringelmann chart readings for August, giving hourly averages in per cent*—Concluded

Baltimore & Ohio shops							
Stack 2		Stack 3		Stack 4		Stack 5	
8 to 9	29. 43	8 to 9	35. 14	8 to 9	31. 08	8 to 9	35. 60
9 to 10	18. 54	9 to 10	37. 93	9 to 10	31. 62	9 to 10	38. 46
10 to 11	33. 02	10 to 11	32. 84	10 to 11	52. 16	10 to 11	37. 64
11 to 12	38. 52	11 to 12	33. 27	11 to 12	36. 42	11 to 12	41. 64
1 to 2	39. 62	1 to 2	36. 74	1 to 2	31. 41	1 to 2	44. 69
2 to 3	38. 44	2 to 3	40. 55	2 to 3	24. 41	2 to 3	62. 80
3 to 4	40. 95	3 to 4	30. 77	3 to 4	38. 16	3 to 4	43. 21
4 to 5	26. 66	4 to 5	24. 95	4 to 5	20. 40	4 to 5	30. 53
Daily average	33. 14	Daily average	34. 02	Daily average	33. 20	Daily average	41. 82

West Virginia & Maryland Power Co.				**Crystal Ice Co.**	
Large stack		Small stack		Two stacks	
8 to 9	27. 95	8 to 9	22. 66	8 to 9	36. 60
9 to 10	19. 45	9 to 10		9 to 10	29. 82
10 to 11	24. 24	10 to 11	16. 49	10 to 11	18. 69
11 to 12	16. 66	11 to 12	11. 33	11 to 12	27. 32
1 to 2	11. 66	1 to 2		1 to 2	26. 33
2 to 3	17. 08	2 to 3	27. 41	2 to 3	29. 91
3 to 4	27. 45	3 to 4		3 to 4	28. 96
4 to 5	7. 00	4 to 5		4 to 5	25. 45
Daily average	18. 93	Daily average	9. 73	Daily average	27. 88

Baltimore & Ohio roundhouse, 21 jacks [a]							
8 to 9		9 to 10		10 to 11		11 to 12	
No. 11	45. 25	No. 18	36. 66	No. 6	29. 83	No. 15	22. 06
No. 13	7. 58	No. 9	33. 50	No. 16	29. 16	No. 18	33. 41
No. 21	22. 16			No. 6	26. 58	No. 10	37. 08
No. 10	39. 25			No. 10	23. 75	No. 19	26. 75
				No. 20	25. 08	No. 15	24. 41
				No. 18	20. 16	No. 11	42. 75
						No. 15	34. 66
1 to 2		2 to 3		3 to 4		4 to 5	
No. 7	47. 00	No. 6	46. 25	No. 4	27. 08	No. 7	27. 91
No. 4	19. 58	No. 8	31. 41	No. 15	25. 58	No. 5	33. 83
No. 15	19. 41	No. 8	21. 83	No. 18	37. 58		
No. 5	37. 66	No. 11	28. 08	No. 21	28. 41		
No. 15	36. 58	No. 10	31. 75	No. 17	40. 75		
				No. 8	25. 75		
				No. 10	52. 00		
				No. 15	47. 75		

Home laundry	
8 to 9	21. 45
9 to 10	24. 94
10 to 11	24. 63
11 to 12	24. 62
1 to 2	23. 78
2 to 3	20. 87
3 to 4	23. 45
4 to 5	26. 28
Daily average	21. 25

[a] Gives hourly average for each jack.

TABLE 6.—*Ringelmann chart readings for September, giving hourly averages in per cent*

Baltimore & Ohio yards near business district

	Opposite depot	Opposite shops	Opposite roundhouse
8 to 9	41.41	37.79	35.87
9 to 10	41.45	35.75	27.70
10 to 11	58.91	55.66	31.12
11 to 12	58.16	59.33	28.91
1 to 2	62.09	40.91	35.83
2 to 3	61.91	47.00	50.75
3 to 4	65.25	55.49	40.41
4 to 5	45.74	25.16	52.15
Daily average	53.11	44.63	37.84

Baltimore & Ohio shops

	Stack 2	Stack 3	Stack 4	Stack 5
8 to 9		22.45	38.16	50.20
9 to 10		24.41	37.61	37.91
10 to 11		39.66	41.40	42.79
11 to 12	66.50	51.16	36.12	48.70
1 to 2		49.96	39.98	50.56
2 to 3	38.58	29.33	56.75	56.33
3 to 4		30.53	42.95	47.70
4 to 5		38.33	42.16	42.75
Daily average	52.59	35.72	29.36	47.11

	Crystal Ice Co.	Home Laundry	Pumping station
	Two stacks	One stack	One stack
8 to 9	31.28	30.78	38.50
9 to 10	27.20	24.95	29.66
10 to 11	35.37	22.33	24.91
11 to 12	37.18	23.37	34.41
1 to 2	38.66	24.28	29.16
2 to 3	25.08	21.83	48.33
3 to 4	31.04	26.83	28.83
4 to 5	30.33	25.45	40.08
Daily average	32.01	24.95	34.22

Baltimore & Ohio roundhouse, 21 jacks [a]

8 to 9		9 to 10		10 to 11		11 to 12	
No. 19	22.91	No. 16	32.33	No. 14	37.58	No. 21	37.00
No. 20	34.41	No. 19	41.08	No. 10	29.00	No. 19	20.58
No. 11	34.08			No. 8	43.83	No. 18	50.16
No. 14	29.16					No. 8	36.16
						No. 12	34.25
1 to 2		**2 to 3**		**3 to 4**		**4 to 5**	
No. 17	24.33	No. 15	29.08	No. 7	29.25	No. 11	24.33
No. 11	42.66	No. 10	29.00	No. 12	41.15	No. 19	33.83
No. 18	28.91	No. 15	26.66	No. 6	42.25	No. 4	33.83
		No. 16	32.66	No. 18	24.50		

[a] Gives hourly average for each jack.

TABLE 7.—*Ringelmann chart readings for October, giving hourly averages in per cent*

Baltimore & Ohio yards near business district					
Opposite depot		Opposite shops		Opposite roundhouse	
8 to 9	38. 33	8 to 9	12. 00	8 to 9	24. 25
9 to 10	23. 33	9 to 10	23. 83	9 to 10	21. 12
10 to 11	37. 99	10 to 11	33. 61	10 to 11	34. 33
11 to 12	43. 03	11 to 12	21. 50	11 to 12	24. 28
1 to 2	43. 78	1 to 2	30. 95	1 to 2	23. 49
2 to 3	40. 44	2 to 3	40. 05	2 to 3	29. 16
3 to 4	30. 44	3 to 4	42. 44	3 to 4	34. 80
4 to 5	24. 99	4 to 5	30. 83	4 to 5	25. 75
Daily average	35. 30	Daily average	29. 40	Daily average	27. 02

TABLE 8.—*Ringelmann chart readings for November, giving hourly averages in per cent*

Baltimore & Ohio yards near business district					
Opposite depot		Opposite shops		Opposite roundhouse	
8 to 9	36. 56	8 to 9	28. 99	8 to 9	37. 31
9 to 10	32. 99	9 to 10	38. 23	9 to 10	43. 74
10 to 11	33. 32	10 to 11	36. 60	10 to 11	38. 24
11 to 12	32. 06	11 to 12	31. 64	11 to 12	34. 01
1 to 2	45. 68	1 to 2	30. 52	1 to 2	20. 93
2 to 3	41. 23	2 to 3	34. 92	2 to 3	34. 06
3 to 4	38. 26	3 to 4	43. 91	3 to 4	27. 30
4 to 5	37. 73	4 to 5	43. 58	4 to 5	34. 93
Daily average	37. 22	Daily average	36. 04	Daily average	33. 81

TABLE 9.—*Ringelmann chart readings for December, giving hourly averages in per cent*

Baltimore & Ohio yards near business district					
Opposite depot		Opposite shops		Opposite roundhouse	
8 to 9	20. 33	8 to 9	18. 66	8 to 9	22. 75
9 to 10	19. 83	9 to 10	14. 66	9 to 10	19. 25
10 to 11	19. 59	10 to 11	20. 22	10 to 11	15. 54
11 to 12	22. 38	11 to 12	18. 49	11 to 12	14. 08
1 to 2	22. 91	1 to 2	20. 20	1 to 2	10. 83
2 to 3	16. 50	2 to 3	21. 66	2 to 3	15. 50
3 to 4	18. 08	3 to 4	13. 58	3 to 4	18. 12
4 to 5	18. 46	4 to 5	25. 83	4 to 5	19. 28
Daily average	19. 76	Daily average	19. 16	Daily average	16. 94

TABLE 9.—*Ringelmann chart readings for December, giving hourly averages in per cent*—Continued

Baltimore & Ohio shops					
Stacks 2 and 3		Stacks 4 and 5		Stack 6	
8 to 9	33. 50	8 to 9	43. 16	8 to 9	30. 08
9 to 10	26. 83	9 to 10	35. 04	9 to 10	25. 50
10 to 11	28. 33	10 to 11	31. 50	10 to 11	17. 00
11 to 12	24. 62	11 to 12	39. 87	11 to 12	19. 70
1 to 2	34. 54	1 to 2	37. 75	1 to 2	31. 74
2 to 3	27. 16	2 to 3	43. 16	2 to 3	25. 75
3 to 4	32. 20	3 to 4	30. 00	3 to 4	25. 58
4 to 5	28. 95	4 to 5	41. 08	4 to 5	28. 83
Daily average	29. 51	Daily average	37. 69	Daily average	25. 28

Baltimore & Ohio roundhouse, 21 jacks[a]			
8 to 9	9 to 10	10 to 11	11 to 12
No. 8 28. 00	No. 18 10. 50 No. 15 13. 27	No. 6 33. 25	No. 6 34. 33 No. 14 16. 25
1 to 2	2 to 3	3 to 4	4 to 5
No. 6 9. 00 No. 12 10. 08	No. 11 11. 91 No. 18 15. 33	No. 14 24. 83	No. 8 22. 41 No. 16 23. 66

[a] Gives hourly average for each jack.

Average daily smoke density, 19.68.

TABLE 10.—*Daily average smoke densities*

Locality	April	May	June	July	August	September	October	November	December
Baltimore & Ohio yards:									
Opposite depot	47. 18	45. 12	47. 11	36. 85	37. 15	53. 11	35. 30	37. 22	19. 76
Opposite shops	37. 65	42. 67	41. 09	34. 90	42. 22	44. 63	29. 40	36. 04	19. 16
Opposite roundhouse	25. 70	37. 47	30. 12	15. 73	26. 66	37. 84	27. 02	33. 81	16. 94
Baltimore & Ohio shops	33. 17	35. 85	42. 96	28. 65	35. 54	41. 19	36. 22	37. 32	30. 82
Baltimore & Ohio roundhouse jacks	23. 14	20. 63	29. 85	32. 09	31. 44	33. 03	28. 36	30. 00	19. 68
West Virginia & Maryland Power Co	23. 14	28. 28	27. 28	25. 73	14. 33	-------	-------	-------	-------
Crystal Ice Co	28. 29	28. 28	29. 32	29. 66	27. 88	32. 01	29. 86	29. 24	28. 62
Home Laundry	-------	-------	23. 20	30. 18	21. 25	24. 95	26. 19	23. 59	24. 89

SOOT-FALL STUDY

The amount of solid material precipitated from the atmosphere was determined by means of a soot-fall study. A number of points were selected at which jars were placed to collect the soot and other material. The location of the soot-fall jars is shown below:

Location of soot-fall jars placed April 7, 1922

Jar 1. 76 Lincoln Street, shed in rear.
Jar 2. Compton's garage, Main Street at bridge.
Jar 3. Cohen's store, Main Street.
Jar 4. Hendrickson's store, shed in rear.
Jar 5. Sentinel Building, Latrobe Street.
Jar 6. Grafton High School.
Jar 7. 427 West Main Street, shed in rear.
Jar 8. Acme Ice Cream Co., west side.
Jar 9. 211 Grand Avenue, shed in rear.

The jars were 6½ inches in diameter and 7 inches high. They were collected every 30 days, when clean receptacles were substituted. The contents of the jars were then filtered on filter paper (see Pl. XII), dried, and weighed. The weight of precipitate was then calculated to tons per square mile per annum. Results for the various locations are shown in Tables 11 and 12.

TABLE 11.—*Soot fall in Grafton*

[Calculated in tons per square mile per annum]

No. of jar	Location	April	May	June	July	August	September	October	November
1	76 Lincoln Street	219	348	394	215	279	395	789	804
2	Compton's garage	....	2, 177	3, 224	3, 827	2, 297	4, 212	5, 001	5, 908
3	Cohen's store	3, 398	2, 127	3, 514	2, 207	3, 492	3, 731	3, 834	2, 220
4	Hendrickson's store	3, 146	4, 115	3, 882	3, 964	3, 876	....	7, 180	4, 567
5	Sentinel Building	2, 188	2, 330	2, 185	1, 692	2, 250	3, 506	6, 683	4, 896
6	High school	380	138	316	172	162	351	456	548
7	427 West Main Street	475	365	455	318	....	510	845	676
8	Acme Ice Cream Co	808	986	443	486	231	658	936	1, 596
9	211 Grand Street	215	383	476	127	620	472	....	....

TABLE 12.—*Composition of precipitated solid matter*

No. of jar	Location	Ash and noncombustible, per cent	Combustible, per cent	No. of jar	Location	Ash and noncombustible, per cent	Combustible, per cent
1	76 Lincoln Street	53. 55	46. 45	6	High school	42. 95	57. 05
2	Compton's garage	47. 35	52. 65	7	427 West Main Street	48. 45	51. 55
3	Cohen's store	43. 93	56. 07	8	Acme Ice Cream Building	41. 72	58. 28
4	Hendrickson's store	46. 27	53. 73	9	211 Grand Street	42. 61	57. 39
5	Sentinel Building	50. 75	49. 25				

Study of the soot fall brought out an interesting point. Similar studies made in a number of States have included the soot precipitated from the smoke of a miscellaneous collection of power plants, heating plants, and other fuel-using equipment as well as locomotives.

The character of the deposit varies widely with the type of furnace in which the fuel is burned. Low-temperature fires, with a low rate of combustion, like those in residence heating plants, and open fireplaces discharge the maximum amount of soot to the atmosphere. On the other hand, the material discharged from high-temperature fires burning coal at a relatively high rate of combustion does not show such high soot content.

Owing to the use of natural gas for residences in Grafton and the dominating influence of the railroad, the term "soot-fall study," may be considered a misnomer. Locomotives do not discharge soot in the sense that that term is generally understood. The material thrown out of the stack of a locomotive consists of partly consumed combustible material or coke, which has been produced in a fire with an extremely high rate of combustion and is entirely different from soot as ordinarily found.

In this study the "soot" consisted largely of unconsumed coke or cinders. The amount of precipitation varied directly with the proximity of the collecting jars to railroad traffic. During October and November the traffic increased greatly over previous months, and locations affected by this condition showed a consistent increase in the amount of material collected in the jars—this without any particular reference to the smoke produced.

ATMOSPHERIC FILTRATIONS

To have as many different means of comparing progress in smoke abatement as possible is desirable. Each of the methods taken to determine atmospheric conditions clarifies the situation from a different angle and offers a method of checking future progress. Atmospheric filtrations were undertaken at various places by filtering a given amount of air (1,000 cubic feet) through a U-tube filter, the air being drawn through a meter by means of a motor-driven exhauster (see Pl. XI, *B*). Then these tests were made at Compton's garage, Cohen's store, the Post Office, the high school, and 415 West Main Street. Plate XIII shows tubes from these five locations. As the quantities of material dealt with were minute it was not always possible to draw accurate deductions from the weights, but the degree of concentration of impurities is readily evident and varies directly with the distance from the down-town section of the city.

FUEL SURVEY

Grafton lies in the eastern part of the great bituminous coal area of the State. Freeport and Kittanning coals are mined within a short distance of the city.

Although the domestic fuel most used is natural gas, a small amount of coal is used for heating and cooking. A large part of this coal is supplied by wagon mines within hauling distance of the city. The analysis of Black Diamond coal, shown below, can be taken as representative of this service.

There are only three regular sources of supply for the Baltimore & Ohio R. R.—Galloway, Hercules, and Sandlick—although other coals are used occasionally in the terminal.

The analyses in Table 13 will indicate the quality and characteristics of the coals mined in the district.

TABLE 13.—*Analyses and heating values of coals mined in the territory about Grafton*

Name of coal	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	B. t. u.
Sandlick	3. 17	35. 24	53. 26	8. 33	2. 79	13, 422
Hercules	. 85	37. 50	49. 60	12. 05	3. 25	14, 277
Berryburg No. 1	. 95	40. 90	50. 20	7. 85	3. 46	14, 096
Willard No. 1	1. 45	37. 65	56. 45	4. 45	1. 37	14, 275
Century No. 1	1. 05	37. 31	56. 10	5. 54	1. 01	14, 305
Century No. 2	. 95	40. 40	52. 95	5. 70	2. 84	14, 430
Galloway No. 2	. 60	38. 05	54. 75	5. 60	2. 12	14, 448
Galloway No. 3	. 60	40. 15	53. 45	5. 80	2. 70	14, 596
Black Diamond	1. 75	34. 76	54. 08	9. 41	2. 54	13, 554

As the table shows, the average volatile content of the various coals is almost exactly 38 per cent. Hence these coals are to be regarded as very smoky, needing large quantities of air for combustion of the volatile matter. The comparatively low content of ash is a favorable characteristic, because it makes possible the operation of furnaces with no unusual amount of trouble. The tonnage used in the various classes of service is given in the table below.

Distribution of fuel used in Grafton April 1, 1921, to April 1, 1922

	Tons
Baltimore & Ohio shops	11, 821
Baltimore & Ohio yards	13, 897
Dispatched engines	22, 397
Baltimore & Ohio roundhouse	14, 952
Crystal Ice Co	2, 000
West Virginia & Maryland Power Co	5, 921
Royal Window Glass Co	1, 200
Home laundry	216
Domestic use	2, 000

Consumption of natural gas during same period

	Cubic feet
Domestic use	296, 605, 500
Industrial use	726, 053, 000
	1, 022, 658, 500

The percentage of dense smoke from the various sources named is as follows:

TABLE 14.—*Percentage of dense smoke from sources named*

	Per cent
Baltimore & Ohio yards	22. 35
Baltimore & Ohio dispatched and road engines	36. 61
Baltimore & Ohio shops	18. 03
Baltimore & Ohio roundhouse	12. 26
Crystal Ice Co	2. 34
West Virginia & Maryland Power Co	6. 35
Home Laundry	. 20
Royal Window Glass Co	1. 19
Domestic use	. 67
	100. 00

SUMMARY OF CONDITIONS AT GRAFTON

From the facts set forth, it can be seen that smoke conditions in Grafton are influenced by a number of local factors that make the situation particularly difficult. The combination of high hills, low wind velocity, fogs, heavy railroad traffic, and the situation of the business district immediately adjacent to the greatest railroad activity, is probably not duplicated in any other railroad center in this country. In addition, the fact that for many years railroad operation had gone on without any smoke supervision whatever naturally made the atmospheric conditions far from ideal.

Locomotives in country districts having no smoke supervision show an average smoke density of 49 per cent. At Grafton the density of locomotive smoke during the first three months of observation equaled and often exceeded this figure. Individual engines under observation during this time showed smoke densities higher than had ever before been recorded in any smoke campaign in the United States.

The soot-fall studies made during the investigation confirmed the results obtained by the Ringelmann chart readings. The fall of solid matter recorded in the down-town section is as high as any on record.

The damage caused by this condition is difficult to figure in dollars and cents. It has been one of the main factors in holding back the growth of the city, and for this reason alone the loss to the community has been incalculable. It is customary to estimate the loss per capita due to the presence of smoke. The cost of the extra cleaning of rugs, carpets, curtains, household furniture, and interior and exterior decoration; laundry, and wear and tear on clothing, and the effect on stocks of goods in warehouses and stores are included. The estimated per capita damage by smoke in American cities has ranged from $12 to $17 a year, the estimates being based on the judging of local conditions, and on careful study over a period of time. In comparison with other localities where this per capita damage has been estimated, the first three months' observations at Grafton would indicate an estimate of $30 per capita, or a direct loss of $300,000 a year as conservative. To this figure must be added the enormous but intangible loss to the community through the continual smokiness.

SOURCES OF SMOKE AND MEANS FOR RELIEF

That smoke conditions in the city could be greatly bettered was shown by the work of the last three months of the campaign. Some of the means that were available for relief are outlined on following pages.

As is evident from the foregoing study, smoke from railroad activity of one form or another is responsible for practically 90 per cent of all the smoke in the territory. Various sources of railroad smoke are briefly discussed below.

ROUNDHOUSE SMOKE

Experiments during the last 10 years have demonstrated that smoke from roundhouses can be reduced to a minimum by the judicious use of blowers and by the proper method of starting fires. The proper method of building a furnace fire with a high-volatile coal such as is used in Grafton is to start the fire from the top, after the grates have been covered with a 5 or 6 inch layer of green coal. The coal rapidly ignites over the entire surface of the fuel bed and forms a film of fire through which the volatile matter, or smoke-forming material, in the lower layer of coal must pass and become more or less completely consumed, without the formation of soot and smoke. Roundhouse smoke in various localities has been attacked by this method with satisfactory results.

In Grafton a system of firing up locomotives with oil torches is in use which lends itself well to this method of operation. In connection with the judicious use of the blower, as mentioned above, and care in lighting fires it should reduce the smoke from the roundhouse to a very small proportion of the whole.

CINDER PITS

Cleaning fires on the cinder pit is generally productive of much smoke. This smoke can be greatly reduced by igniting the fresh coal from the top, as in starting a new fire. At cleaning time the fire is pushed toward the flue sheet and the front section of the grates is cleaned of ash and clinker. Then fresh coal is thrown on the grates and the live coals are raked from the front end of the fire box up over this fresh coal, igniting it from the top as before. Any plan that will keep the fresh coal underneath and the fire on top will aid in accomplishing the desired result.

ENGINES IN YARD

A large amount of the smoke made in Grafton comes from engines held under steam in the yard. Smoke from this source can be controlled by careful firing and the proper use of the blower. Fires can be built up without black smoke. This is a matter of education and training; it should conserve fuel as well as eliminate smoke. In engines equipped with mechanical stokers fires should be built up in the yard with the shovel; then it can be done successfully with a minimum amount of smoke.

ROAD ENGINES

Engines on the road can run without dense smoke if proper methods of firing are used. In an engine going out of the terminal the fire should have been built up gradually in the yard until it is in such a condition that the engine can pull out without heavy firing and with practically no smoke.

When an engine is coming into the terminal the fireman should begin to build up his fire in advance, getting it in such a condition that when the smokeless zone has been reached the engine can proceed without heavy firing and often without any firing at all. Road engines standing on track at the depot or elsewhere can be kept clean by the proper use of the blower, by judicious firing, and possibly by "cracking" the door. There is practically no excuse for black smoke from road engines standing on track.

SHOP POWER HOUSE

The power house of the railroad shops at Grafton has been one of the most consistent sources of smoke. The plant contains a number of old locomotive boilers which carry loads that make forcing necessary, with the consequent production of large volumes of smoke. Plans are underway for the installation of brick arches in these boilers, ring blowers in the stacks, and combustion tubes in the fire boxes. These changes should materially reduce the amount of smoke made. However, the plant itself can be considered as only a temporary installation and it is not to be expected that complete smoke elimination will result from this reconstruction. As a matter of fact plans have been made to replace this plant with a modern boiler equipment which may be made absolutely smokeless. These plans were delayed by the railroad strike of 1922, but will eventually be completed. Elimination of this smoke producer will cut a large percentage from the total smoke of the city and will be one of the most important elements in the eventual cleaning up of the terminal.

LOCOMOTIVE SMOKE-ABATEMENT DEVICES

Standard equipment has been developed for locomotive operation which aids the fireman to keep down smoke while his engine is in the terminal. This equipment has come to be known as the Altoona specifications, because the most careful tests covering this subject were made at the Altoona laboratory of the Pennsylvania R. R. The Altoona specifications are not absolutely necessary for the abatement of smoke from locomotives but they are a material aid to the fireman in his attempts to keep smoke at a minimum. The specifications call for a multiple-tip blower (ring type) placed in the stack and controlled by a quick-opening blower valve or valves in the cab, sometimes one on each side for the engineer and fireman, and a series of combustion tubes located along the side of the firebox about 18 inches above the grates, with steam jets 2¼ inches outside the combustion tube to siphon air into the firebox, thereby supplying the oxygen necessary for complete combustion of the volatile matter. This equipment, in combinaton with the brick arch, which is standard in locomotive practice, completes the installation.

SMOKE-ABATEMENT MEASURES BY THE RAILROAD

In the effort to improve smoke conditions in Grafton, the railroad and other interested parties were asked for cooperation. The response was highly gratifying.

The Baltimore & Ohio management took an unusually strong stand in the matter. Some of the measures that were put into effect during the campaign are listed below:

1. The president, operating vice president, and general manager of the railroad instructed all departments to give the strongest cooperation.

2. W. L. Robinson, of Baltimore, superintendent of fuels and locomotive operation, was assigned to oversee the work and assist in every possible way through the various branches of the motive power division.

3. The entire divisional staff, including the road foreman of engines, master mechanics, engineers, firemen, hostlers, fire builders, fire knockers, and all persons who were in any way connected with smoke production, was assembled at various times for instruction in methods of smoke abatement. The first meeting was held October 7, 1922, when the general proposition was discussed and a comprehensive plan for attacking the problem laid out. Later meetings were arranged to take in the first, second, and the third trick men and motion pictures were employed to bring out the features and new methods which it was desired to use.

4. The force was increased by two men on each trick to assist in handling the power, watch fires, etc.

5. An experienced locomotive fireman, trained in smoke abatement in Philadelphia, Baltimore, and Washington, was assigned to the yard with the title of smoke inspector. His duty was to instruct the firemen in the proper handling of their fires to reduce smoke.

6. Three inspectors of fuel economy, one on each of the divisions running into the terminal, were assigned, with special reference to the instruction of engine crews coming in and going out of the territory.

7. One additional road foreman of engines was assigned to work in the territory and instruct firemen.

8. Smokeless zones were established. When an incoming locomotive engine reaches this zone, no firing, or at most, very light firing, is permitted. Firemen are being instructed regarding methods of operation inside the zone, and discipline is sometimes administered where the rules have been flagrantly violated.

9. Road supervision has been increased on road engines passing through, in order that such engines shall have enough equipment and be in such condition as will insure satisfactory operation while in Grafton.

10. A general checking up of locomotive operation at the terminal is under way in order that the firemen will build up their fires to proper condition for entering the terminal and turn over engines to the crews handling locomotives in the yard with fires in such shape that the smoke can be kept down. This instruction also applies to the men handling locomotives in the yard before they are sent out on the line. The men must see that the engines have proper steam pressure, water level, and fires in such condition that the locomotives can proceed out of the terminal without heavy firing until the smokeless zones have been passed.

11. A rearrangement of coal distribution has been effected so that as much lump coal as possible shall be placed on hand-fired engines.

12. An approved oil torch, used at Cincinnati, has been adopted for firing up engines in the yard, and an expert from the Cincinnati terminal was imported to instruct the operators in the use of this torch, which has been very successful in reducing smoke.

13. Air blowers are being used in connection with firing up.

14. Special attention is being given to brick arches, as this equipment has an important bearing on smoke abatement.

15. A special report card has been instituted to check incoming and outgoing engines and remove the possibility of avoiding responsibility when an engine has been found in poor condition for its work. This check system enables correction to be applied quickly and the proper instruction given to persons responsible in order that the mistake will not recur.

16. Hostlers are being sent to the Washington, D. C., yards to observe methods in use there and get instructions for the work at Grafton.

17. Extensive work which will reduce smoke has been done in connection with the shop power house. The steam lines have been repaired, reducing steam consumption; and the air line leading to the east yard has been rebuilt, 2,500 feet of new line being installed. These improvements have a marked influence on the air-compresser load and the consequent coal consumption of the plant. The air compressers themselves have been overhauled. Blowers have been installed in stacks and brick arches in the fire boxes of these boilers. Combustion tubes have been applied for admitting auxiliary air and a special grade of coal has been arranged for, which has shown by experience to reduce the volume of smoke. Two new boilers are being installed.

RESULTS OF CAMPAIGN

Table 15 shows the percentage of dense smoke, according to the December readings, from the various sources named in Table 14.

TABLE 15.—*Percentage of dense smoke from sources named, December readings*

	Per cent
Baltimore & Ohio yards	19. 26
Baltimore & Ohio dispatched and road engines	31. 00
Baltimore & Ohio shops	27. 12
Baltimore & Ohio roundhouse	14. 63
Crystal Ice Co	4. 26
West Virginia & Maryland Power Co	0. 00
Home Laundry	. 37
Royal Window Glass Co	2. 17
Domestic use	1. 19
	100. 00

As mentioned before, the smoke-density readings given in the tables for the first three months of the campaign (Tables 1, 2, and 3) are taken to represent the conditions before any smoke-abatement work was done.

The figures for the same territory and same class of smokers, represented by the observations for December (Table 9), are taken to represent conditions after smoke-abatement measures had been put into effect. It is not to be understood that the conditions represented by the December readings are as good as can be obtained, or that all of them are satisfactory. They simply show the degrees of smoke abatement that it was possible to obtain in the time available and indicate the results that may be expected from consistent efforts exerted over a long period of time. The per cent reduction in smoke of the various groups, as indicated by the average smoke-density figures for December, are as follows:

Reduction of smoke:	Per cent
Engines opposite depot	57
Engines opposite shops	54
Engines opposite roundhouse	45
Roundhouse jacks	34
Shop power house	17

These average figures, although they show a gratifying measure of reduction, do not do full justice to many individual engines in yards and on the main line, as many of them had smoke-density figures over long periods of time of only 8 to 10 per cent. This means for those engines a smoke reduction of 75 per cent as compared with former conditions.

When it is considered that none of the smoke-abatement measures outlined in this report were in existence before October 7 and that all of the progress reported here was accomplished within 60 days, it will be realized with what efficiency and vigor the problem was attacked. Moreover, during this period the road handled the heaviest volume of traffic passing through the terminal in several years without inconvenience or delay. It is probable that no similar campaign has ever been able to show such results in such a short time.

RECOMMENDATIONS

When future plans are made, it must be remembered that Grafton is an important railroad terminal, and that the location of the city and the weather changes, such as fog and air currents, and all other factors influencing the atmospheric conditions are extremely unfavorable. Railroad traffic through and in this terminal can not be carried on without the production of some smoke, as long as coal-burning locomotives are used, and the combination of light smoke and fog, with the peculiar topography of the district, will operate to the disadvantage of the city. Effort should be concentrated on the limitation of dense smoke—that prohibited by smoke ordinances—and of all unnecessary smoke, such as that due to carelessness.

Experience in other localities has shown that the larger part of the smoke can be eliminated by cooperative and educational methods and that prosecution for smoke violations is generally unnecessary until after some years, when persistent offenders who have defied all efforts at cooperation may be brought into court. Cooperation at Grafton has been extended freely and the policy of the city in the future should take into consideration the fact that it is to the interest of the railroad, because of fuel economy, to keep smoke-abatement measures in force.

The organization of the city government does not provide machinery ample for the administration of a smoke ordinance as the term is generally understood, nor does the situation demand that such an ordinance be passed now. It is enough to have on the books a clause prohibiting the emission of dense smoke to cover emergencies and special situations which may arise in the future conduct of the work. Such a prohibition clause may be inserted as an amendment to the existing city ordinances, carrying the same penalty that applies to such ordinances, as follows:

[Amendment to ordinance 5-a of the charter ordinances and by-laws of the City of Grafton, W. Va.]

> The emission of dense smoke within the city from the smokestack of any locomotive, steam roller, steam derrick, steam pile driver, or other portable or temporary smoke-making device or apparatus for a period of more than one minute, except for a period or periods aggregating not to exceed six minutes, in any one hour, during which period or periods the fire box or boxes are being cleaned or a new fire or fires are being built therein, is hereby declared a nuisance.
>
> The emission of dense smoke within the city from the smokestack of any tar kettle or similar contrivance, or from the smokestack or chimney of any building, or premises, or from any open bonfire, open bin, tank, vat, basin, or other receptacle, except for periods aggregating not to exceed six minutes in any one hour, during which periods the fire box is being cleaned or a new fire is being built therein, is hereby declared a nuisance. Any nuisance, such as the above specified, may be summarily abated by anyone duly authorized by the city for such purpose and such abatement may be in addition to the penalty provide in this ordinance. Smoke shall be considered dense when it is of equal or greater density than No. 3 of the Ringelmann chart, or smoke too dense to be seen through when viewed directly over the top of the stack.

The use of soft coal for domestic purposes will gradually extend as the supply of natural gas decreases. It should be the effort of the city and of civic bodies to see that all householders are supplied with instructions on the proper handling of soft coal in stoves, grates, and furnaces. Such literature is available and will be amplified from time to time by additional issues of various publications, including bulletins of the Bureau of Mines. This instruction should be thorough enough to insure that domestic smoke will not become a factor in the atmospheric condition of the city.

For the larger and more important power and heating plants that may be built from time to time, the city would do well to follow some standard code for furnace installation, such as the Cincinnati code.

As a record of progress and annual check-up on smoke conditions it would be desirable to have readings taken, selecting some month, such as November, for comparison with prior readings. The psychological effect of this would be valuable and the expense would be less than that of maintaining a smoke inspector throughout the year.

Observations indicate that the greatest need in the situation is an increased spirit of cooperation between the city and the interests which are using coal in the district. Such cooperation will produce better and more lasting results than any other measure which might be applied.

PUBLICATIONS RELATING TO COAL SMOKE

A limited supply of the following publications of the Bureau of Mines has been printed. Requests for copies available for free distribution should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the cost of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION

BULLETIN 39. The smoke problem at boiler plants, a preliminary report, by D. T. Randall. 1912. 31 pp.

BULLETIN 49. City smoke ordinances and smoke abatement, by S. B. Flagg 1912. 55 pp.

TECHNICAL PAPER 80. Hand firing soft coal under power-plant boilers, by Henry Kreisinger. 1915. 83 pp., 32 figs.

TECHNICAL PAPER 273. Smoke abatement, by Osborn Monnett. 1923. 31 pp., 12 pls., 4 figs.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS

BULLETIN 1. The volatile matter of coal, by H. C. Porter and F. K. Ovitz 1910. 56 pp., 1 pl., 9 figs. 10 cents.

BULLETIN 23. Steaming tests of coals and related investigations, September 1, 1904, to December 31, 1908, by L. P. Breckenridge, Henry Kreisinger, and W. T. Ray. 1912. 380 pp., 2 pls., 94 figs. 50 cents.

BULLETIN 37. Comparative tests of run-of-mine and briquetted coal on locomotives, including torpedo-boat tests and some foreign specifications for briquetted fuel, by W. F. M. Goss. 1911. 58 pp., 4 pls., 35 figs. 15 cents.

BULLETIN 40. The smokeless combustion of coal in boiler furnaces, with a chapter on central heating plants, by D. T. Randall and H. W. Weeks. 1912. 188 pp., 40 figs. 20 cents.

BULLETIN 135. Combustion of coal and design of furnaces, by Henry Kreisinger C. E. Augustine, and F. K. Ovitz. 1917. 140 pp., 1 pl., 45 figs. 20 cents.

TECHNICAL PAPER 34. Experiments with furnaces for a hand-fired return-tubular boiler, by S. B. Flagg, G. C. Cook, and F. E. Woodman. 1914. 32 pp., 1 pl., 4 figs. 5 cents.

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